Catching Air and the Superman

by D. Andrew Stewart

SCHULICH SCHOOL OF MUSIC
MCGILL UNIVERSITY, MONTREAL
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TABLE OF CONTENTS

Volume 1 – Analysis of *Catching Air and the Superman*

ABSTRACT | RESUME

This two-volume dissertation contains an analysis text (Volume 1) of the complete musical score for *Catching Air and the Superman* (Volume 2), which is an approximately fifteen-minute, one-movement composition for sixteen musicians. It features interactive electronics through an integration of gestural controllers, known as t-sticks, and acoustic instruments. In total, three digital instruments are heard in the work: MIDI keyboard and two soprano t-sticks. The acoustic instruments constitute a chamber orchestra: flute (piccolo), oboe, clarinet, tenor saxophone, baritone saxophone, trumpet, trombone, two percussion, two violins, viola and violoncello. The following analysis begins with a contextual examination of electronic music technology in relation to the compositional project. Next, the concepts and models of *Catching Air and the Superman* are outlined. The remainder of Volume 1 contains a detailed discussion pertaining to: compositional structure and form, spectral and pitch space, object and motif, rhythm, timing and tempo.

Ce document en deux volumes comprend une analyse (volume 1) de l'intégralité de la partition (volume 2) de *Catching Air and the Superman*, une composition pour seize musiciens, en un mouvement, d'environ quinze minutes. L'œuvre fait intervenir à la fois des éléments électroniques, contrôlés par deux interfaces gestuelles, appelés t-sticks, et des instruments acoustiques. Au total, trois instruments électroniques peuvent être entendus dans cette pièce : un clavier MIDI et deux t-sticks sopranos. Les instruments acoustiques constituent un orchestre de chambre comprenant : une flûte (piccolo), un hautbois, une clarinette, deux saxophones, un ténor et un baryton, une trompette, un trombone, deux jeux de percussions, deux violons, un alto ainsi qu'un violoncelle. L'analyse qui suit débute par un historique de l'évolution de l'usage des technologies électroniques en composition pour arriver au contexte de ce projet spécifique. Les concepts et modèles intervenant dans *Catching Air and the Superman* sont présentés à la suite de cet historique. Le restant du volume 1 comprend une discussion détaillée des aspects suivants : structure et forme de la composition, espace spectrale et champ des hauteurs, traitement des objets sonores et travail motivique, rythmes, minutage et tempo.

Acknowledgements

First and foremost I wish to extend my gratitude to those musicians – those performing and scientifically-minded musicians – without whom the outcome of my work would have been much less enriching and surely meagre in comparison to the advancements we made as an interdisciplinary team while working at the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT), as well as the centre's satellite studios and laboratories such as the Digital Composition Studios (DCS) and Input Devices and Music Interaction Laboratory (IDMIL). My doctoral research was supported by both CIRMMT (the CIRMMT Director's Interdisciplinary Excellence Prize) and the McGill Digital Orchestra Project (funded by the Fonds québécois de recherche sur la société et la culture). A special 'thank you' goes to one of the music technologists in our team, Joseph Malloch, for having an appreciation of going beyond concept.

I am also indebted to my two advisors, Professors John Rea and Sean Ferguson (director of the DCS), in more ways than can be expressed in this short paragraph. Through their distinctive means, each of my advisors has thoughtfully directed me toward my own sense of compositional craft. Furthermore, I wish to thank Professor Denys Bouliane as well as the digital and acoustic instrumentalists of the Contemporary Music Ensemble of McGill for their dedicated interpretation of my *Catching Air and the Superman*.

The performance of my composition was also made possible through the technical support of the DCS and its Chief Electronics Technician, Richard G. McKenzie. The usage of the digital musical instruments was granted by Professor Marcelo M. Wanderley (director of the IDMIL) and Joseph Malloch. In assembling the text of my dissertation, I wish to recognise the contributions of friends and colleagues Dr. Michael Nafi, Bryan Jacobs and Dr. Nicolas Gilbert.

Expressing gratitude to the one you love is insufficient in cases such as this. Fortunately, this gesture also promises an awakening of personal journeys and engenders the sharing of new knowledge. Thank you Isabelle.

List of examples

Example 1-1. Musicians Lindsay Roberts and Eric Derr performing *Catching Air and the Superman* on soprano t-sticks (digital musical instruments).

1. Chapter 1 – Introduction

1.1. Document overview

The first volume of this two-volume dissertation contains a nine-chapter analysis of my composition, *Catching Air and the Superman* (*CAS*), for MIDI keyboard, two soprano t-sticks (Example 1-1) and chamber orchestra. Volume 1 begins with a contextual examination of electronic music technology in relation to the compositional project. Next, I explain the essential features of the t-stick, followed by the concepts and models of *CAS*. The remainder of the volume contains a detailed discussion pertaining to compositional structure and form, spectral and pitch space, object, motif, rhythm, timing and tempo. A compact disc containing numerous audio and video examples from Chapter 5 accompanies the first volume.[1] Four appendices conclude Volume 1. They contain: a short one-page example displaying 'raw' timing values that the reader may find useful while learning about my mapping objectives and rhythmic grids; general digital musical instrument specifications and brief performance notes for the piece; staging and technical notes and set-up diagrams; a list of my completed works for digital instruments (i.e., t-stick, rulers, HandSonic, SonicJumper). The complete musical score (Volume 2) follows Volume 1.

1.2. A description of the composition

CAS is an approximately fifteen-minute work. It features interactive electronics and the integration of acoustic and digital musical instruments. A digital musical instrument (DMI) consists of a control surface, or gestural controller, which drives the parameters of a sound synthesis algorithm in real-

[1] The contents of the CD are encoded in basic HTML. Access all of the audio and video examples by inserting the disc into a computer and opening the file, entitled 'Documents', with a standard web browser. Refer to the 'ReadMe' file included on the disc for more information. Alternatively, this analysis is available as an e-thesis with embedded audio and video examples. Contact the author for more information, as well as audio and video examples that document the premiere performance of *CAS*.

time. The MIDI keyboard is included in this definition, thus my project calls for three DMIs in total.

At the compositional centre of *CAS* are evocations of bouncing, breaking, divergence and convergence. In my piece, bouncing and breaking are considered as a single concept (**3.4**)[2], having an impact on all the major constituents of the piece including structure and form (**4.5)**, DMI spectral space (**5.1)**, keyboard pitch space (**6.3)**, object (**7.2**), motif (**7.3.2)** and rhythm (**8.6.2)**. Divergence and convergence are equally important, affecting among other things, a broad perception of musical gesture (**3.5.2)**, structure, DMI spectral space, orchestral pitch space (**6.5)**, motif (**7.3.3)** and rhythm (**8.5.1)**. All four evocations (i.e., bouncing, breaking, divergence and convergence) were bound together with the digital technology from the very beginning of the compositional process. In other words, they were intrinsic to the compositional project at the earliest stages of composing. Representations of bouncing, breaking, divergence and convergence came about through the development of the sounds for the keyboard and t-stick. Moreover, I considered the jostling of the t-stick – which is integral to the playing technique of the DMI – as an appropriate visual likeness/representation to the aural evocations of bouncing and breaking. Because of the importance of digital instrument technology in *CAS*, the next several sections of Chapter 1 exclusively deal with situating my work in a larger perspective on the role of technology in music composition.

1.3. The role of technology

The idea of making music with an acoustic instrument is familiar, having been an integral part of Western Classical music for centuries. Composing for instruments requires ageing within the life-span of an individual – the composer – who responds to this calling. In other words, only

[2] Throughout this document, a number in parenthesis and in bold font-weight (e.g., **1.1** or **1.1.1.**) refers to the dissertation section.

through an extended study of musical craft and the rewards this craft may bring does a composer gain the maturity to create a masterwork. Here, I am suggesting that modern composers are still interested in producing compositional masterpieces. Today, composers often look to artistic and scientific integration for a set of tools or procedures for creating important musical works.[3] From the perspective of the experienced composer, one must ask what the role of technology in music composition should be. In the following paragraphs, I will answer this question through an examination of historical contexts.

1.4. Historical contexts

I will refer to technology initially as the mechanical apparatus through which composers introduce non-acoustic instrumental sound into their compositional projects. As the discussion in this chapter proceeds, the reader will detect a broadening definition of technology to include, on the one hand, modern day digital micro-circuitry that bears little resemblance to a lay-person's conception of a mechanical apparatus, and on the other hand, technology as a computer interface, seen by composers as a means of creating and performing a musical composition. The latter case can be understood as an electronic musical instrument through which performing musicians explore new modes of expressiveness.

1.4.1. Futurism

For me, the implementation of digital instruments in *CAS* primarily corresponds to the broader understanding of technology suggested above. Nonetheless, the sounds I create with DMIs recalls the mechanical apparatus or machinery described in a manifesto from 1913, by Luigi Russolo, a painter and contributor to the early Futurist movement that was initially centred in

[3] Integrating the arts and sciences is not a new endeavour of humanity; however, this integration is highly visible today because of a technological pervasiveness in how we interact with each other and with the infrastructure of our developed society.

France and Italy.[4] In this document, entitled *The Art of Noises*, Russolo describes the Futurists' outlook on 'noise music', in addition to their instructions on performance and declamation.[5] Their approach combined music and theatre in a way that was vehemently criticised by the public at the time. During a performance of music by Balilla Pratella,[6] Luigi Russolo's conception of noise music was confirmed: Russolo heard machine sounds as a viable form of music, and suggested that the birth of noise occurred at the same time as the invention, in the nineteenth century, of the machine (Goldberg, 1979, p. 21). My own compositional thought has very little coincidence with *Futurism*, other than my awareness of the musicality of machine noise and my conviction that a family of electronic instruments will eventually form an established lutherie, recalling Russolo's *intonarumori*.

1.4.2. Sound-producing machines

Despite Russolo and other Futurists' lack of success within music circles, their work was, only a decade later, admired as a precedent for combining music and technology. For instance, the *Machine Age Exposition* (1927), in the Steinway Hall, New York, gave prominence to the work of the Futurists, while spotlighting the impact of the machine age on developments in music in America. A fascination with technology came to be linked to a widespread aesthetic of the day. During the 1920s, a considerable amount of attention was first given to new electronic instruments such as the telharmoninum (1897, revealed to the public in 1906), the theremin (1919, patented in 1928), ondes martenont (1928) and trautonium (1929). From the

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[4] An earlier manifesto, entitled *Le Futurisme*, by Filippo Tommaso Marinetti (1909), was first published in the Paris daily, *Le Figaro*, and is considered to be the first document laying out the broad tenets of Futurism.

[5] *Dynamic and Synoptic Declamation* (Piedigrotta, 1916) was another Futurist manifesto, instructing proponents/actors on the correct declamation style: dynamic and warlike (Goldberg, 1979, p. 18).

[6] Francesco Balilla Pratella (1910) was an Italian composer and Futurist, and author of *The Manifesto of Futurist Musicians*.

1930s and 1940s, we also have the croix sonore (1934), ondioline (1941), electronic sackbut (1948) and mixtur-trautonium (1949).[7] Furthermore, composers around this period imagined a musical future that evolved through the development of sound-producing machines. For example, Edgard Varèse, who immigrated to New York in 1915, was a proponent of musical liberation through science. Consider the following from his 1939 article, *Music as an Art-Science*.

> And here are the advantages I anticipate from such a machine liberation from the arbitrary, paralyzing tempered system; the possibility of obtaining any number of cycles or, if still desired, subdivisions of the octave, and consequently the formation of any desired scale; unsuspected range in low and high registers; new harmonic splendors obtainable from the use of sub-harmonic combinations now impossible, the possibility of obtaining any differentiation of timbre, of sound-combinations; new dynamics far beyond the present human-powered orchestra, a sense of sound-projection in space by means of the emission of sound in any part or in many parts of the hall, as may be required by the score; cross-rhythms unrelated to each other, treated simultaneously, or, to use the old word, "contrapuntally", since the machine would be able to beat any number of desired notes, any subdivision of them, omission or fraction of them – all these in a given unit of measure or time that is humanly impossible to attain (2004, p. 19).

Only after World War II did the means exist for realising Varèse's vision.

1.4.3. Performance art

In the meantime, developments in other domains nurtured the integration of the arts and sciences. For example, Western 'performance art' used the theatre as a laboratory for investigating the intersection among things such as: space, form, colour, light, sound, movement, time and other phenomena. Here, I am thinking of the experimentation at Black Mountain College in North Carolina in the 1930s. An interdisciplinary approach to art at the college was especially endorsed by college instructors such as Josef and

[7] Not all of these electronic instruments originated in The United States. A number of them came from inventors in France, Germany and elsewhere.

Anni Albers and Xanti Schawinsy, all of whom shared a history with the Bauhaus.[8] 1948 was a particularly important year at Black Mountain because of the inclusion of two new tutors to the institute's summer school: the composer John Cage and choreographer/dancer Merce Cunningham. The experimentation of Cage and Cunningham at Black Mountain advanced performance art in America and anticipated the so-called 'happenings' and the formation of Fluxus in the 1960s.[9] New directions proposed by John Cage, in particular, had a lasting effect on the 'experimental music'[10] of the 1950s and 60s, especially as they pertained to concepts of *process* and *control* in music. Consequently, an intersection of the doctrines of performance art and the evolution of music technology (circa 1950-60s) met in John Cage's compositions such as: *Cartridge Music* (1960), *Variations IV* (1964), *Variations V* (1965) and *Rozart Mix* (1965). I intentionally detoured from the role of technology (my central focus, stated in **1.3**) in this section in an effort to contextualise briefly the role of electronics in John Cage's music. Next, I consider in detail several key points concerning his implementation of technology from the perspective of my own work.

1.4.4. John Cage

After 1960, Cage became fascinated by technical-musical collaborations. The multidisciplinary teamwork behind his music represented remnants of performance art from the first half of the century and brought composers, engineers and performers together, along with dance and visual

[8] The Bauhaus (first situated in Weimar, then Dessau, Germany) was a teaching institution for the arts with international notoriety (1919-32). The Bauhaus policy called for a unification of all the arts and a synthesis of art and technology (Goldberg, 1979, p. 97).

[9] Examining the threads of performance art of the twentieth century is beyond the scope of this dissertation. Nevertheless, I wish to state that I attribute a modern day trend toward collaborative music research to the consistent theme of interdisciplinary experimentation in performance art (from Futurism and Dada, through Bauhaus to Fluxus).

[10] This term may stem from a course taught by Cage at the New School for Social Research in New York, in 1956 (Goldberg, 1979, p. 127).

artists. For instance, *Variations V* combined a massive Bauhaus or Black Mountain-like multidisciplinary team of:

> Cage and Cunningham; dancers Carolyn Brown and Barbara Lloyd; composers/musicians Fredric Lieberman, Malcolm Goldstein, James Tenney, David Tudor and Gordon Mumma; visual artists Stan VanDerBeek (film sequences and collages) and Nam June Paik (television image distortion); synthesizer builder Robert Moog, who designed and built twelve five-foot high movement-sensitive antennas; a group of engineers at Bell Labs, who built a set of small focussed light-sensitive photocells (Miller, 2002, p. 160-61).

The merging of disciplines provided a unique opportunity for Cage and his collaborators to take the first steps toward defining 'live electronics' (**1.4.5. Live electronics**). My own work for the t-stick is indebted to the type of technical-musical collaboration initiated by Cage.[11] For instance, the initial conceptual design of the t-stick was a result of numerous workshops and dialogues between myself and a music technologist. Later on, acoustic instrumentalists joined us in developing the foundations for t-stick performance practise (the DMI's development is briefly summarised in **2.3. The t-stick**). Consequently, I was able to develop consistent DMI playing techniques and their respective sounds for *CAS*.

Cage's embracing of technology was indicative of a compositional desire for a wider sonic palette – accessing the sounds of our wide-open sound world – controlled from the performance space. Here, his work derived, in part, from an earlier dialectic of, and between, noise and percussion – percussion instruments enjoying a more autonomous role in music composition (e.g., Varèse's *Ionization* [1932]). To some extent, his ideas could also be understood as a natural extension of 'tape music' techniques through a combination with live performance (e.g., Berio's *Differences* [1958-59] and Stockhausen's *Kontakte* [1960]), and/or combining significantly different electronic music studio techniques in one piece (e.g., Stockhausen's *Gesang*

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[11] Pierre Boulez's political writings of the 1970s also helped, leading to the formation of IRCAM in the last part of that decade (Jameux, 1984, p. 17).

der Jünglinge [1956], Pousseur's *Scambi* [1957], Berio's *Thema: Omaggio a Joyce* [1958], Cage's own *Fontana Mix* [1958]). The wealth of sound possibilities afforded by the t-stick is a natural extension of Cage's diversification of the sonic palette with small-scale electronic technology, especially because a live performance element is implicit in both cases. In other words, the t-stick allowed me to fuse the wide-open sound world particularly heard in electronic music composition with active on-stage music-making.

Cage's experimental music (e.g., *Variations V*) also coincided with a particular phase in commercially available technology (circa mid-1960s). People like Robert Moog and Donald Buchla had begun marketing compact and small-scale versions of the large and extensively equipped North American electronic music studios located in major institutions (e.g., Bell Laboratories, Columbia Tape Studio [later the Columbia-Princeton Electronic Music Center], Canada's National Research Council, University of Toronto, McGill University, University of Illinois). Cage's predilection for these flexible and practical electronic systems made up of simple components that could be linked in such a way as to produce complex results in the context of a live musico-theatrical performance is evidence of his contribution to the popularity of modern day interactive hardware objects and modular software synthesis applications (e.g., Max/MSP, PD, OpenMusic, Kyma, BEAST). Assembling the sensor-driven technology of the t-stick (**2.3. The t-stick**), for example, is in-line with a contemporary momentum toward creating interactive objects or environments with flexible, easy-to-use open-source electronics.

John Cage's application of technology in the postwar era reflected an underlying aesthetic dispute about concepts of control.[12] At the time, a political debate arose questioning the role of modern media as either (1) technology for encouraging creativity and the responsibility to promote a free exchange of information, or (2) technology aimed at curtailing individuality and imposing mass culture (Brooks, 1993, p. 311). In short, do media confine or liberate? Another concept of control dealt with a broadening fissure between popular and Western art music and the function each had in defining the future of music. For example, the live performance aspect of Cage's experimental music could be seen as a shift away from the well-planned and well-sculptured musical work – the composition – toward the spontaneous performance and from the composer to the performer. In popular music, performers and small groups, amplified by technology, seemingly became more important than composers. In addition, the postwar recording industry imposed a uniformity on musical culture *via* the production of unprecedented quantities of recordings. Simultaneously, the same technology provided portable recording gear for composers – or anyone for that matter – empowering them to create their own specialised forms of music. The result was a dialectic of creativity and consumerism, whose resolution would determine who would control the future modes of music-making.

Creativity and consumerism are not an immediate concern in *CAS*; however, the predominance of performers over composers, or vice versa, may serve as a talking point in my piece. On the one hand, an examination of the score for *CAS* attests to my dominion over the t-sticks' musical gestures and, thus, an indirect control over the performers' activities. On the other hand, performers undergo an unusual liberation by having the wide-open sound

[12] Cage implemented his portable electronic technology in a way that was conducive to the overriding process of indeterminacy in his music. His approach contrasted with concurrent ideas on power and precision from composers such as Milton Babbitt (Columbia-Princeton Electronic Music Center) and Stockhausen (NWDR, Cologne). For a further discussion of this topic see William Brooks' (1993, p. 328) writing on The Americas, 1945-70.

world in their palms. Here, I am suggesting that we associate an authority over rich amplified sound spectra to empowerment, especially when sounds are obviously controlled by one's physical manipulation of a gestural controller such as the t-stick. *CAS* provides a forum in which to continue the debate over the importance of performers and composers – a debate brought to the fore in Cage's experimental music and commercially popular music.

1.4.5. Live electronics

Musical works employing portable on-stage electronic resources – as in the cases of *Kontakte* and *Variations V* – maintained the 'live' human performer firmly in the centre of focus, thus the prominence of the performer would characterise a growing body of music that became known as 'live electronics'. Collectives of performing artists led the way in implementing live electronics (e.g., the Fluxus group, Sonic Arts Union, Musica Elettronica Viva, Canadian Electronic Ensemble). In the 1950s and 60s, the on-stage live electronic components comprised: phonographs, magnetic tape, short-wave radios, simple voltage-controlled oscillators and all of the elements of a sound amplification/diffusion system (microphones, mixing consoles, etc). In addition to manipulating the above, performers played electronic instruments (e.g., electronium, EMS Synthi) and traditional acoustic instruments; acoustic instruments (including voice) provided a live input that was simultaneously modified through electronic processing (e.g., amplification, feedback, ring modulation). The manipulation of acoustic instruments was, and still is, a predominant feature of live electronics.

Novel electronic interfaces were also part of the performer's inventory, especially toward the end of the 1960s and into the 70s. For example, the cybersonic console was developed for Gordon Mumma's *Hornpipe* (1967).[13] The console, which hung off of the belt of a musician playing a natural horn, essentially acted as a feedback device for integrating the sound of the horn

[13] The cybersonic device was a concept that originated with the Sonic Arts Union (Mumma, Behrman, Ashley, Lucier) in the 1960s (Nyman, 1974, p. 101).

with the natural acoustical properties of the performance space. The cybersonic console monitored both the sound of the instrument and the resulting resonance in the space. Subsequently, it modified acoustic instrumental sound or introduced new sounds as a result of the internal gate-controlled circuitry of the device. Michael Nyman suggested that the function and placement (i.e., worn by the musician) of the cybersonic console enabled "one to see very clearly how electronics may be literally an extension of the player and his instrument" (1974, p. 86).

In the 1970s, the commercial success of new electronic interfaces, especially those modelled on the keyboard paradigm, made possible the rapid proliferation of university electronic music studios and the private ownership of a powerful technology.[14] Moreover, composers viewed the technology as a means of maintaining a fair degree of precision and control during a live electronics performance.[15] I see their position, therefore, as providing another significant historical perspective on distinguishing the role of technology in music composition.

1.4.6. Gestural controllers

The movement towards today's digital micro-circuitry in music technology began with the massive vacuum tube computers at Bell Telephone Laboratories in 1957. A durationally short sound from these machines took hours to calculate. Many years of hardware development occurred before the first digital instrument, the Allen Computer Organ, was publicly unveiled in 1971. From this point, digital instruments slowly evolved through early synthesizers such as: the Dartmouth Digital Synthesizer (1973); the New England Digital Corporation's Synclavier (1977); the Samson Box, or Systems Concepts Digital Synthesizer (1977); 4A to 4X synthesizers

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[14] A boost in the presence of electronic instruments for live performance took place in the 1970s following the advent of the modular analog synthesizer in the mid-1960s from makers such as Moog and Buchla (Brooks, 1993, p. 312).

[15] Jon Appleton, John C. Eaton, Terry Riley, Morton Subotnik and John Watts, among others, quickly adopted new devices into their compositional practise (Brooks, 1993, p. 337).

developed at IRCAM (1976-80); the first commercially available device, the Fairlight Computer Music Instrument (1979); the Yamaha GS1 (1980); the Yamaha DX7 (1983); Kurzweil (1984). The DX7, in particular, marked a turning point in the early 1980s for several reasons: its relatively low cost; its reliance on a single specialised synthesis technique (i.e., frequency modulation); Yamaha's implementation of the MIDI protocol, which had just been ratified; and the implementation of a novel breath-controller/interface. The early 1980s also saw an increased availability of affordable microprocessors (i.e., personal computers), which made their way onto the equipment lists of composers of live electronics.

The advancement and miniaturisation of digital technology of the 1980s, when combined with the portable on-stage electronic systems of the previous two decades, gave way to a new category of live electronics composition that entailed processing sound by interacting with a computer *via* an interface or input device. Initially, the keyboard and wind instrument paradigms dominated the conception of an input device. However, over the last two decades, new modes of interfacing with a computer – and the computer's increasingly powerful on-board software synthesizers – have resulted in a rethinking of input devices and the paradigms upon which they are based. A 'gestural controller' is one type of input device that encompasses a range of different paradigms, primarily based on a performer's physical movement. The concept of a gestural controller, therefore, has its origins in the merging of fast and affordable personal computers with live electronics and more importantly, a need to couple computer interaction and physical gesture. For an understanding of gestural controllers, in relation to digital musical instruments, refer to the next chapter (**2. Digital musical instruments**).

Numerous musicians, especially performers, have observed an absence of the human (physical) gesture in the context of interactive electronic music

(Appleton, 1984; Schrader, 1991; Emmerson, 2000; Ostertag 2002; McNutt, 2003; Schloss, 2003). That is, audiences may have no idea what cause produces what musical effect, especially when an electronic instrument's control surface (i.e., gestural controller) is separated from its sound – currently a common performance scenario. In this regard, one particular concern I share with Emmerson (2000, p. 206) is that in some gesture-controlled systems the ambiguity of cause and effect leads to a loss of appreciation of human agency. What is music, if not a human action? Generally speaking, the above authors (Appleton, Schrader, Emmerson, etc) share a unified outlook, calling for maintaining a clear action/response or cause/effect relationship between the physical performance gesture and the resulting electroacoustic sound. In one sense, they are essentially arguing for maintaining a traditional sense of stage presence and performance practise with gestural controllers. My concurrence with their viewpoint should be apparent after an examination of t-stick design strategy (**2.3.2**) and playing techniques (**2.3.3**) in the next chapter.

1.5. Summary

After briefly describing the overall structure of this dissertation, I mentioned some of the key features of *CAS*. In particular, I gave a quick glimpse of how concepts drawn from real-world sound scenarios (e.g., bouncing and breaking) influenced the musical materials of the composition. Furthermore, I hinted at a correspondence between these concepts and the role of digital technology in my piece. The remainder of this chapter mapped out the trajectory of the evolution of music technology in the twentieth century by focusing on how composers conceived of, and performed on, electronic devices and instruments.

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2. Chapter 2 – Digital musical instruments

2.1. Introduction

A digital musical instrument comprises a control surface (i.e., gestural controller, input device) and a sound generation unit, both of which are independent modules and are linked *via* liaison strategies between the output signals of the control surface and the input parameters of the sound unit (Miranda and Wanderley, 2006, p. 3). In this chapter, I discuss my own four constituent definientia of a digital musical instrument. By defining a DMI, I intend to address my question (from **1.3. The role of technology**) on the relationship between technology and the compositional project and to situate *Catching Air and the Superman* within the continuum of historical approaches described in Chapter 1. I conclude the chapter by detailing technical and performance aspects of the t-stick.

2.2. The four constituents of a digital musical instrument

Constituent 1. A digital musical instrument is a gestural controller used by musicians for active on-stage music-making.

Constituent 2. A digital musical instrument is accompanied by an established playing technique and a flexible sound synthesis engine.

Constituent 3. A digital musical instrument requires performance expertise and must be practised.[16]

Constituent 4. A digital musical instrument must form an integral whole with the musical concepts and materials of any composition in which it is employed.

Regarding the first constituent of this definition, I subscribe to Axel Mulder's (2000) (1) touch, (2) expanded range and (3) immersive gestural controller classification as an appropriate system for initially defining what mechanical form a DMI might take, although some details of Mulder's

[16] This dissertation does not document the six-month training period I undertook with my two soprano t-stick players, nor does it describe the autodidact methodology and interdisciplinary research surrounding my own study of the DMI over the last four years.

classifications may be at odds with my own definition of a DMI. For example, electroencephalogram and biosignal sound art may entail the use of 'immersive' controllers. However, if the sound art does not entail bodily movement – which is often the case – then the immersive controller does not meet my definition of a DMI. Another device not matching my definition is the ubiquitous computer keyboard (as used in laptop ensembles, for example), which falls under Mulder's classification of 'touch' gestural controllers. Using the computer keyboard does not elicit any particular musically meaningful movements during a performance. Moreover, its function as a focal point during a music concert ambiguously intermingles with our cultural understanding of a laptop/personal computer as a tool for interfacing with the infrastructure of our society (e.g., browsing the internet, checking e-mail) – not a particularly artistic endeavour. A DMI should be understood as an extension of the body in the same way as an acoustic wind instrument (including the voice) may be conceived as an extension of human speech, or the reach of a percussion mallet to drum head as an extension of the arm. Moreover, according to my definition, a DMI is used to maintain the action/response relationship consistently found in music-making, thus centring the performance focal point on the human agent. My definition preserves the dominant performance role of the human musician in live electronics and maintains notions of precision and control through a clear cause/effect co-ordination.

In my second constituent defining a DMI, I advocate developing a fixed set of physical playing gestures *per DMI* while inventing an unlimited sound array for DMI 'voice' on a *per project* basis. Multiple layer mapping[17] and design principles are at the centre of this approach. Mapping the human body movements necessary to execute a particular manipulation of a gestural

[17] I subscribe to a definition of mapping that includes the "connection between gestures, or structures and audible results in a musical performance or composition" (Doornbusch, 2002, p. 145).

controller, regardless of the sonic result, is first and foremost. That is, the first layer of mappings connects a performer's natural, intuitive and learned handling of a DMI to functional control data. The next mapping stage entails thoughtfully coupling control data to synthesis algorithm parameters in a way that guarantees a clear action/response or cause/effect relationship for both the performer and the audience. By following this approach, I believe we assure both the longevity of a digital instrument and our ability to transpose the instrument from composition to composition by virtue of the DMI's lack of dependence on a static sound synthesis engine. In my view, this is conducive to composing electronic music, which inherits a great independence of sonic material and sound synthesis techniques. Contrary to this method, composers sometimes build project-specific technology that may or may not have any use after the completion of the project. I consider this approach as failing to exploit fully the malleable nature of technology to its fullest extent. That is, a single flexible technology can be cleverly designed to fulfil as large or as small a technical and creative niche as necessary, on a *per project* basis, while also remaining adaptable to numerous other creative endeavours.

An essential component of my third constituent of defining DMIs concerns the investment of time and effort that is required while practising and developing expertise on a musical instrument. Learning how to play a DMI parallels acoustic instrumental practise, consisting in lengthy training sessions and private practising. Training operates on two levels. Firstly, it results in well-performed music. Mastering a well-defined and established playing technique helps an audience to perceive a piece of music as being well-performed. Secondly, the level of training acts on the musician. By gradually perfecting playing technique, a performer can become engaged with the instrument thanks to an understanding of the idiomatic nature of the DMI. Consequently, he or she feels more at ease and more capable of exploring his or her expressive urges *via* the instrument. That is, mastering technique is intimately tied to any attempt at expressiveness by the musician. In this way, we can measure the skill level of a musician, in addition to evaluating the potential of a DMI to offer new possibilities for expressiveness to the musician.

Out of all the facets of my definition of a DMI, my fourth constituent is the most crucial: a DMI must form an integral whole with the musical concepts and materials of the compositional project. With this part of my definition I am emphasising the value and significance of compositional training. I would like to reiterate that composing for a DMI is less about the digital instrument – less about the technology – and more about the compositional idea behind the music (refer to **1.3. The role of technology**). If a composer includes a DMI in the instrumentation and material of a project, then he or she must dedicate time and effort to fully understanding the digital instrument in order to make the DMI intrinsic to the composition. Furthermore, he or she must consider what new possibilities working with DMI technology can bring to the compositional project. These might include, for example:

- Expanding the sonic palette (recalling past viewpoints from Futurism, Edgard Varèse and Cage)
- Defining new modes of composing and a new music that reposition the composer as equal, at the least, to the performer (evolving concepts of process and control, **1.4.4. John Cage**)
- Integrating a DMI as an extension of a musician's presence (suggested by Nyman, **1.4.5. Live electronics**)
- Exploring new modes of expression by focussing on a concurrence, or purposeful counteraction, between physical playing gestures and the sonic result, possibly leading to a musico-theatrical composition, for example (**1.4.6. Gestural controllers**)
- Exchanging expertise among composers, performers and music technologists, leading to both a heightened understanding of science and also the possibility of creating a broader appreciation of music as a whole (not unlike the dynamics of 'performance art')

The next sections of this chapter concern the t-stick digital musical instrument.

2.3. The t-stick

2.3.1. Technical description

The t-stick is a physical input device that senses where and how much of its surface is touched by the performer, and detects gestures such as tilting, shaking, squeezing or twisting (Malloch, 2007, p. 66). The t-stick is built with a structural substrate of ABS or PVC plastic pipe, to which sensors are affixed. (Example 2-1) The interface features multi-touch capacitive sensing on one side accomplished using discrete strips of copper tape as sense electrodes.[18] It also features 5 independent axes of acceleration sensing (an accelerometer at each end of the DMI), pressure sensing surface (on the side opposite the copper electrodes) and a piezoelectric contact microphone for sensing deformation of the controller as a result of tapping, hitting or twisting. Several different versions of the t-stick have been developed. Some models incorporate vibration actuators for programmable haptic feedback. All sensors are sampled using an internal micro-controller fastened within the PVC plastic pipe, and the sensor data are sent to a computer using either wired USB, or Bluetooth or ZigBee wireless protocols. In the current operating

Example 2-1. The soprano and tenor t-sticks.

[18] The ‘t’ in t-stick comes from an earlier name, the tiger stick. It has been suggested that with the copper tape electrodes exposed (Example 2-1), the appearance of the t-stick calls to mind the stripes of a tiger.

mode, sensor data from the t-stick is received by the serial object in Max/MSP.[19] The data is then manipulated within Max/MSP and converted into the Musical Instrument Digital Interface (MIDI) protocol. MIDI messages are subsequently sent to a software synthesizer. My choice of synthesizer in *CAS* was a physical modelling module from LogicPro[20] called Sculpture (Example 2-2). Each soprano t-stick controls two instances of Sculpture. One instance is predominately responsible for producing long sustained tones while the other is more percussive and features a sharp onset. I describe t-stick timbre more thoroughly in Chapter 5 (**5.4. T-stick spectral space**).

Example 2-2. Screen shot of the Sculpture graphical user interface.

2.3.2. Design strategy

The design strategy behind the t-stick included developing (1) the outer shape and dimensions of the DMI, (2) the sensor technology allowing a user to interface with the instrument actively and most significantly, (3) the multi-

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[19] Max/MSP is a graphical music programming environment originally conceived in 1986 at IRCAM (*Institut de Recherche et de Coördination Acoustique/Musique*) in Paris. Available from Cycling '74 <www.cycling74.com>.

[20] Apple's integrated system for composing, producing and scoring music.

layer mapping techniques that allow for concurrence between a user's manipulation of the DMI and the sonic result. A consistent mapping aim has been to encourage performers to focus simultaneously on both the sound of the DMI and the relation of sound to the entire instrument, rather than having them think about individual sensor mappings. Generally speaking, well-designed mapping layers help a DMI performer in two ways. Firstly, they enable the performer to recall playing techniques on his or her instrument in a consistent fashion – identifying the control parameters of an instrument is as important as how an instrument sounds and what it looks like. Secondly, as a result of a thoughtful approach to mappings, a playing technique makes itself evident and meaningful for the performer, who is then required to develop his or her competencies with the DMI. In this respect, the t-stick is designed to be played by expert musicians. Emphasis is placed on allowing performers to make expressive decisions based on their musical intelligence, intuition and reading of the score. To this end, prominence is given to extending any ceiling on virtuosity rather than on lowering the 'entry-fee'. New users should be able to produce sound from the t-stick, but not necessarily musically pleasing sound.

2.3.3. Playing techniques

Performing on the t-stick is solely accomplished through the physical handling of the DMI.[21] No type of computer score following or computer-assisted composition is required. Early in 2005, I began experimenting with t-stick playing techniques, which then evolved through an interdisciplinary project with acoustic instrumentalists, composers and music technologists.[22] I further shaped the techniques into their current form following the completion of the project in March, 2008.

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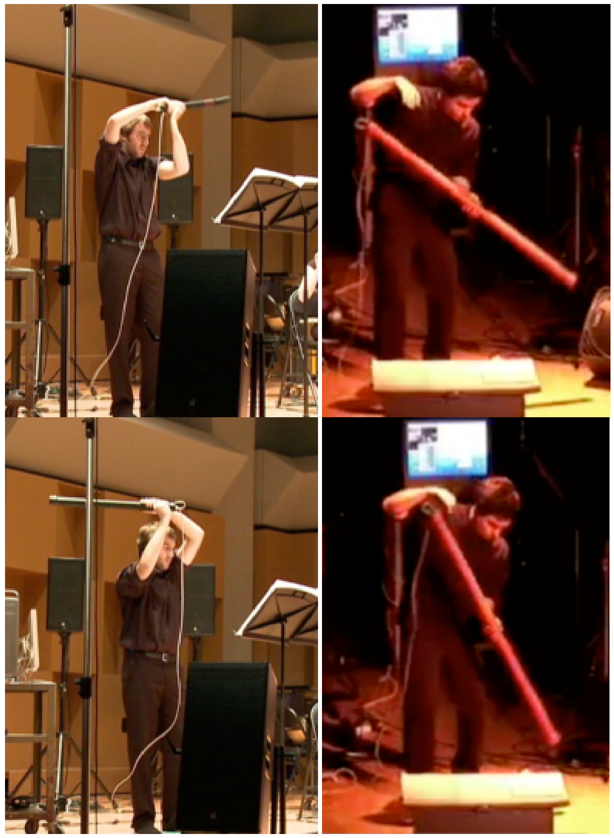
[21] On occasion, I have augmented the t-stick set-up with large FSR (pressure-sensing) floor tiles. The purpose of the FSRs is to provide an additional control over the global volume of the t-stick, despite the numerous methods of manipulating volume with the DMI directly.

[22] The McGill Digital Orchestra Project (Pestova, X., Donald, E., Hindman, H., et al., 2009).

I describe the instrument's playing techniques broadly as either 'malleable' or 'intractable'. By 'malleable', I mean techniques (i.e., physical playing gestures) that are easily repeatable and reproduce a consistent sonic result. Malleable techniques are what give performers an immediate 'feedback' recognition of their instrument. For instance, malleable techniques generate sonic gestures such as (1) initiating a sound, (2) articulating a sound (e.g., varying the timbre of an onset) and (3) *crescendi*/*diminuendi*. These three are fundamental to any digital or acoustic instrument and need to be easily effectuated by performers. Example 2-3 illustrates t-stick techniques for initiating a sound.

Example 2-3. D. Andrew Stewart performing his work *Everybody to the power one* and illustrating the malleable techniques of initiating a sound by fingering (left) or jabbing (right).

The term 'intractable' refers to playing techniques that afford a great amount of timbral nuance and subtlety. Accordingly, they primarily entail either minute or expanded fluid and shifting physical movements such as tilting and rotating the t-stick (see Example 2-4, below). For instance, in the score I have specifically named intractable performance techniques that visually extend the arms, via the t-stick, and mimic the movement of a large fan ('fan'), the twirling of a lasso ('lasso') or the revolving of an airplane

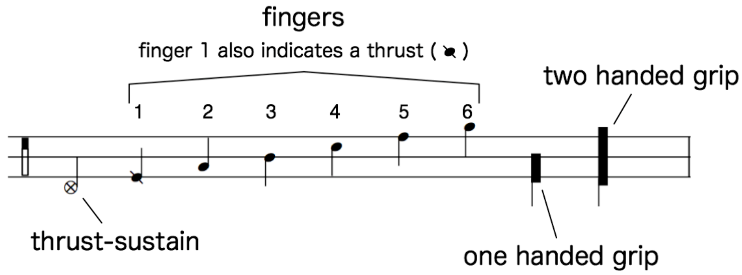


Example 2-4. Intractable techniques. Eric Derr (left) twirling the soprano t-stick overhead (i.e., 'lasso') in *Catching Air and the Superman*. Fernando Rocha (right) tilting the tenor t-stick in *The One* (by the author).

propeller ('airplane'). They are intractable in that maintaining a rigid and static timbre through these techniques is difficult. Mastering the intractable attributes involves learning how to maintain a sense of constant transition among different timbral states and not necessarily how to reproduce repeatedly any timbre at the drop of a hat. Intractable playing techniques rely on performer proficiency, as well as subjectivity, dictated by musical intelligence and intuition. As a result, their successful execution goes a long way toward conveying performer expressiveness.

2.3.4. Notation

The music for the t-stick is represented in two associated forms: a printed musical score and a software graphical interface of my own design. In the printed score, music for the t-stick is notated on a three-line staff (see Example 2-5, below). The top and bottom lines of this staff coincide with the

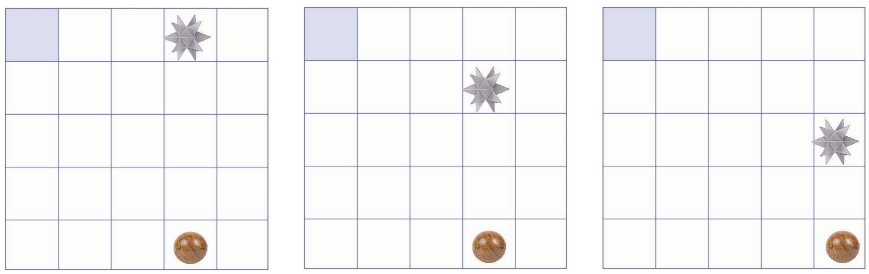


Example 2-5. Three-line staff and notational symbols of the t-stick.

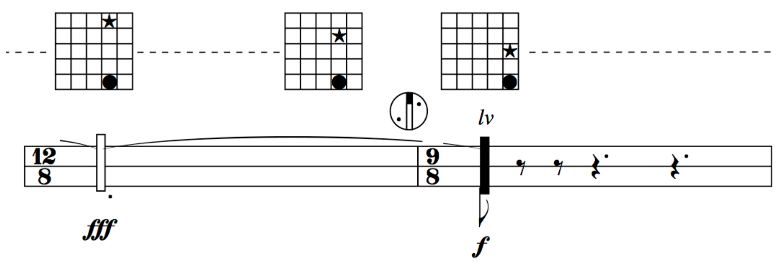
top and bottom of the touch sensing range, respectively. The top of the range denotes the end of the instrument that is furthest away from the USB port; the bottom of the range indicates the end nearest to the port.

Musical notes and thin vertical blocks on the staff indicate an approximate placement of single fingers (traditional note-heads) and hand grips (vertical blocks) on the t-stick. The range of sounds is variable and depends upon a musician's control of timbre, which is indicated by t-stick tablature grids located above the staff. I speak more about the t-stick tablature notation in relation to Examples 2-6 and 2-7, below. A slash through a note-head specifies a thrusting or jabbing motion with the t-stick and consists in: (1) selecting hand position; (2) tilting and rotating the instrument (and one's own body); and (3) applying a proper degree of force not only in the direction of the jab but also to grip pressure. An encircled 'X' (i.e., ⊗) below the staff specifies a technique known as a 'thrust-sustain', which is an adaptation of the jabbing technique. The thrust-sustain requires a minimum of a 0.75-second preparation time during which the performer must maintain a consistent degree of pressure (on the pressure-sensing side of the DMI) before executing the jabbing movement. The result may be anything from a series of sustained cacophonous bell-like tones to a brittle and woody bubbling, depending on the degree of pressure used. Changes in volume are traditionally notated with standard dynamic symbols: ***f***, ***p***, *crescendo*, etc.. In addition, the *lv* symbol, which is a standard mark for percussion music, is found above the staff and specifies that the sound of the t-stick be allowed to resonate.

The second component of t-stick notation concerns a graphical software interface for displaying a type of dynamically-changing tablature system. I invented both the interface and the tablature system. Generally speaking, the timbre of the t-stick results from both tilt and rotation; however several other factors concomitantly contribute to the resulting sound (e.g., degree and location of surface contact, pressure applied to surface). Symbols (Example 2-6) appearing on a computer screen and above the staff (Example 2-7)



Example 2-6. On-screen t-stick tablature grids.



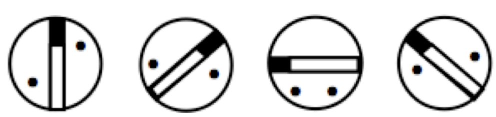
Example 2-7. T-stick tablature, above the staff.

inform the performer about the current tilt and rotation of the instrument, as well as approximate contact positions (i.e., hand positions). In Example 2-6, we see three tablature grids. The circle and star contained within each grid correspond to control parameters of two instances of Sculpture (Sculpture is mentioned in **2.3.1. Technical description**); the circle is related to one instance and the star, the other.[23] During a performance, the grid elements (i.e., circle and star) shift up and down and from side to side corresponding to the physical handling of the t-stick. For instance, tilting the t-stick moves both

[23] The shaded top left corner of each grid has been used in previous versions of the on-screen interface, but not in *CAS*. The shaded corner can be automated so that it moves from square to square.

elements horizontally.[24] The star moves vertically as a result of rotating along the lateral access of the DMI while hand width, combined with hand position along the surface of the DMI, controls the vertical positioning of the circle. During a performance, a musician reads the notated tablature grids in the printed score along with information written on and below the staff. Next, he or she manipulates the t-stick in order to match the on-screen tablature to the notated grids. For instance, the three grids shown in Example 2-6 correspond to the notated musical score grids of Example 2-7. Furthermore, dotted lines appear between notated grids in Example 2-7 and indicate a gradual change from one grid to the next. T-stick playing technique, therefore, requires one to have a swift and accurate grasp of the tablature system so that one can smoothly shift from hand position to hand position while fluidly rotating and tilting the instrument.[25]

One further symbol shown in Example 2-7 needs clarification. Throughout the development of the DMI, I found notated indications for t-stick orientation to be necessary (Example 2-8). While composing *CAS*, I continued to use them even though some similar information was already conveyed by the tablature grids. From my experiences as both composer and performer on the DMI, I have observed that these orientation symbols provide a simple and coherent means of conveying basic tilt and hand position information. For instance, the first symbol of Example 2-8 specifies holding the t-stick upright (i.e., the top of the t-stick pointing upward) and vertical with the left hand on the bottom and the right hand on the top.



Example 2-8. T-stick orientation symbols.

[24] I give photo examples of tilting on page 23 (Example 2-4, right side).

[25] I trained the soprano t-stick players in *CAS* over a period of approximately six months, meeting with them every couple of weeks. The musicians were quick to pick up the tablature system and it proved an invaluable aid in achieving the desired sounds.

2.4. Summary

In Chapter 2, I began with an explanation of my four definientia of a DMI and highlighted the new possibilities digital technology brings to the compositional project. After that, I looked at the technical and design issues of the t-stick and suggested ways in which the instrument conforms to my definition of a DMI. The chapter concluded with details on t-stick playing technique and notation.

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3. Chapter 3 – Concepts and models

3.1. Introduction

The following chapter discusses four key concepts for the analysis of my piece: (1) *Air and the Superman*; (2) *Sound as music*; (3) *Bouncing and breaking*; (4) modelling of *Musical excerpts*. The first two concepts (i.e., Air and the Superman and Sound as music) deal with esthesic concerns. The remaining two illustrate the foundations of the formative principles of *Catching Air and the Superman*. In this chapter, I also bring forward models from within each concept. Furthermore, in several cases, I disclose specific objectives in relation to my piece that stem from these models.

3.2. Air and the Superman

'Air' and 'the Superman' merge into a single concept, although they are represented by distinct musical features – and analogies – and serve separately as models for *CAS*. 'The Superman' is metaphorically represented by the MIDI keyboard chord, or chordal sections, suggesting closure, termination, the last act, the climax and the earth. It is the beginning and ending of any leap. The vehicle for 'Air', on the other hand, is the soprano t-stick, which represents the resonance of a chord, suggesting sustain, pause, breathe, recurrence and eternity. Resonance is both real (i.e., sound reverberation) and simulated (i.e., composed material that repeats, undulates or sustains as a result of a chordal onset). A further interaction between 'Air' and 'the Superman' in the composition can be described as follows.

Imagine the moment of maximum height – and maximum flight – in a single leap. For me, the turn of phrase "catching some air" represents one possible idiom to express this instant in time: a moment of physical suspension interrupting gravitational force. Expressions of this instant can be found in the so-called extreme sports: skateboarding, snowboarding, kite-boarding, as well as BMX bicycle racing and freestyle. Moreover, this moment can also be measured in the concept of 'hang-time' (the period of flight during a 'layup') in basketball. For instance, a long hang-time reveals mastery of the skill and a seemingly superhuman control over body and nature. As a symbol, "catching some air" represents in my mind a kind of timelessness and a human endeavour that leaves an indelible mark for all eternity. Furthermore, catching some air is not a satisfying action when executed only once – extreme sports are evidence of this. On the contrary, it ought to be a repetitive action in which the agent strives for ever greater superhuman power; hence an endlessly increasing extent of power. This also implies that power is unattainable – *Catching the Superman* is unattainable.

3.3. Sound as music

This concept relates to the application of theories from the field of psychophysics to electronic music composition. Psychophysics is firstly described with a primary emphasis on our cross-modal sensory perception. Secondly, I look at the musical use of sound from our wide-open sound world, and the impact of this use on the perception of space in electronic music composition. Finally, I describe how psychophysics and our wide-open sound world interact and manifest themselves as a model and as a set of objectives – under the heading of *The physicality of music*.

3.3.1. Cross-modal sensory perception

A branch of experimental psychology, referred to as psychophysics, informs our understanding of 'being' in space. Psychophysics originated in the late nineteenth century with the German psychologist Gustav Fechner, who attempted to mathematically represent a relationship between psychological sensation and the physical intensity of a stimulus (Fechner, 1966). Later experimental psychologists went on to apply Fechner's principles to other types of stimuli, including sound. For instance, a correspondence has been drawn between our psychological perceptions and the physical properties of a sounding object (McAdams, 1993). Commenting on the recognition of sound sources from the standpoint of an ecological acoustician, McAdams states that we “develop descriptions of the structure of the physical world that make evident the properties that are perceived as being invariant, even though other properties may be changing” (p. 148). In this case, the perceived properties have to do with both “the nature of the resonant structure being set into vibration (resulting from the geometry and materials of the sound source), as well as…the means with which [a sound source] is excited (sliding, striking, bowing, blowing, etc)” (p. 152). A shortcoming of this observation from ecological psychology entails a failure to account for *how* we develop descriptions of the physical world. One explanation may have to do with the nature of cross-modal sensory interactions (i.e., the degree to which information from one sensory channel influences our interpretation of information arising through other sensory channels). In other words, descriptions of the physical world may come from a concatenation of stimuli from all our senses. Seitz (2005) states that:

> Cross-domain mappings, or the ability to integrate information across different sensory modalities, enable us to perceive intensity, spatial location, tempo, and rhythmic structure in an amodal manner. These abilities, moreover, appear to be innate or develop early and rapidly in human development (p. 426).

One may also subscribe to a Darwinian perspective, where our internal sense of self-motion may be thought to have evolved in early hominids to deal with sounds in the environment (Todd, 1992, p. 3549), or to Vines’ argument that a musician’s body movements and corresponding musical sounds arise from the same expressive unit in the performer’s mind – the original expressive unit is conveyed through two complementary channels, each carrying different information content (Vines, Krumhansl et al., 2005, p. 106). Suffice it to say, our recognition of an objects’ physical properties – and its identity as a sound source – is seemingly dependent on our cross-modal sense perception. Moreover, I propose that this correlation extends to our potential recognition of *l'objet sonore* in electronic music composition.[26] Refer to *The physicality of music* (**3.3.3.**, below) for an explanation of the position cross-modal sensing has in determining objectives in *CAS*.

3.3.2. The wide-open sound world

In 1948, the so-called *Concert of Noises*, by Pierre Schaeffer and Pierre Henry, concretely established the musical implications of sound from our wide-open sound world. One must also not ignore the contributions of Luigi Russolo and the futurists (circa 1909) or of Varèse (circa 1931). Schaeffer and Henry's auspicious event not only gave credence to the treatment of environmental sounds as music, it also set forth the tenets of *musique concrète*, which was the first approach to electronic music composition that yielded a substantial repertoire. Among the principles of *musique concrète* – and of great significance in *CAS* – is the abolishing of any sense of hierarchy in ordering sound. Subsequently, both *musique concrète* and *CAS* demand a rethinking of the correct criteria for classifying sound, with the objective of structuring a musical composition. For example, Schaeffer (1966) hypothesised that the future of music would be concerned with a structuring of sound objects, in combination with other objects, in relation to the properties that define a musical space.

What is musical space? Or rather, what is the relationship between music and space? Gilbert Rouget (1985) argues that:

> the sound of music defines the space in which *I* am situated as a space inhabited by men, and at the same time it situates *me* within this space in some particular manner…The sounds I hear mark out the space around me and enable me to integrate myself into it (p. 121).

Here, Rouget suggested that the sounds of nature, for example, bring us information on the movement of the natural world, just as human sounds inform us of our own presence and tell us something about our activities

[26] The concept of *l'objet sonore* is well-documented in Schaeffer's *Traité des objets musicaux, essai interdisciplines* (1966), and originates in the vocabulary surrounding *musique concrète* (circa 1952).

within a space. He also introduces an effective analogy that finds a parallel in the writings of composers such as John Cage and R. Murray Schafer. As Rouget suggests, “Silence is the sign of an empty of motionless space – death or sleep” (Rouget, 1985, p. 121). Music, therefore, psychologically modifies the experience of ‘being’ in space. When a composer deduces a criterion for classifying sound, in fact, he or she is establishing the foundational material with which a musical space (i.e., structure) will be erected. From these few examples, it should be clear to the reader that a musical space can be literal (e.g., the concert hall into which we integrate our being, our body) and poetic or metaphorical (e.g., Rouget’s interpretation of silence and existential ‘being’), and herein lies a hint of one objective in *CAS*: ascribing a dramatic embodiment to a perception of musical space in a composition. The next section unites this topic with cross-modal sensing and more precisely uncovers compositional objectives.

3.3.3. The physicality of music

Through my concept of *Sound as music*, I consider the manner through which the theories of cross-modal sense perception, discussed above, meet the sounds of our wide-open sound world, setting forth a model of the ‘physicality’ of music. It seems necessary to offer a definition of physicality, since it is central to the concept of *Sound as music*. A broad definition of the word is implied. Physical denotes aspects of a musical composition that are primarily perceived through the senses. These aspects are somehow tangible and concrete and may have a connection to the body. That is, music can figuratively imitate a bodily action. In addition, musical physicality may conjure up real-life entities outside the body, from the physical universe. In this way, musical physicality can suggest any human action from intense physical labour to sloth, as well as any human interaction with objects of the external world. The reception of *CAS* should predominantly be dominated by a cross-modal experience that establishes a connection between the evocation of real-world physical objects, along with their real-world physical behaviours, and an appreciation of timbre and compositional form. Consequently, physicality becomes a source of musical tension, as well as a form-bearing element. In the following section, I shall discuss the objectives that arose from the model of the physicality of music in *CAS*.

Framing and occupying the concert stage – the literal musical space – with the musicians of the orchestra is the first objective originating from the model of physicality. The earliest perception of the composition is visual, that is, the work is put before the public on a traditional concert hall stage. From the perspective of the audience, the stage effectively acts as a window onto a three-dimensional landscape, separated from the audience space. The DMIs (i.e., keyboard and two t-sticks) are strategically placed in locations that are easily perceived as the structural pillars of the actual three-dimensional landscape (see **Appendix C**, Example C-1), although the depth of the landscape may appear quite shallow – almost two-dimensional. A deeper three-dimensional space is circumscribed by including the two percussionists (up-stage, one on stage-left, the other on stage-right). Furthermore, the suggestion of increased depth of space is suggested by the timbral integration between percussion instrument sound and the inharmonic quality of the DMI voices. The two soprano t-sticks flank the acoustic instrument ensemble. In this respect, they may be perceived as physically framing or even encapsulating the entire ensemble. The stretch of the t-stick playing technique and expanse of movement (depending on the interpretative attitude of the players) accentuate the role of each instrumentalist as a vigourous supporting pillar. The centrally located keyboard appears to emanate from the heart of the ensemble, thus it acts as a central supporting pole.

Conjuring up real-life entities in the minds of listeners, once the music becomes ongoing, is the second objective having its origin in the idea of physicality. In particular, the real-world inharmonic timbral attributes and behavioural characteristics of bouncing objects occupy much of the composition (refer to **3.4. Bouncing and breaking**). Inharmonic sound colour is emphasised by both the DMI voices – by simulating different transient states and a different weighting of modes, depending on the material of the synthesised bounced object – and the scordatura of the acoustic instrument ensemble. In the latter case, the majority of wind instruments are required to tune downward roughly one quarter tone. Inversely, the flute is asked to tune one quarter tone higher. The clarinet and baritone saxophone are tuned normally. The function of the scordatura is to allow for an enhanced timbral integration between digital and acoustic instrumental timbre. In addition, scordatura plays a role in reinforcing the aural presence of real-world objects by creating a perceptual experience that evokes the machinery of our everyday environment and situates us in a musical space occupied by machines, although the listener may not be able to name every machine. Seeing how the majority of sounds in our everyday environment are inharmonic, the emulation of these sounds, even in part, carries with it source bonds to the physical objects that make up the landscape. The detuning of the chamber orchestra brings the listener closer to a perception of instrumental sound as environmental noise and one may therefore hear instrumental sounds as music.

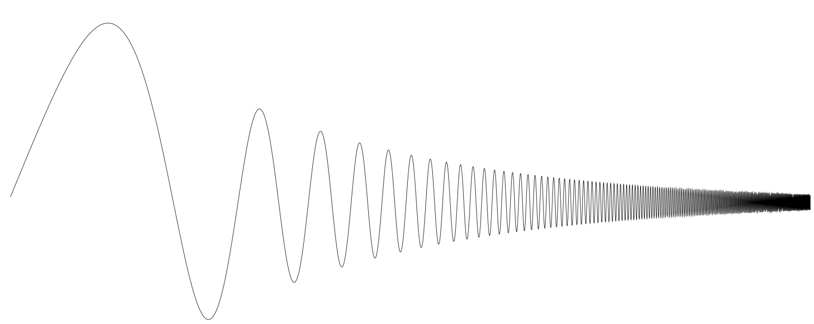
Arousing a perception of objectification through textural rigidity is the third objective emerging from the physicality model. Repeatedly expressing and prolonging textural relationships between instruments and instrumental families permeates each moment of the composition with a tangible presence, personality and concreteness. Moreover, the highly measured modulation or morphing of textures adds a further characteristic or consistency by which whole sections of the piece can be perceived as an object – like the highly measured labour of whipping cream into butter.

3.4. Bouncing and breaking

The bouncing and breaking concept is the first of two concepts used to lay the groundwork for the key formative principles of *CAS*. The emulation of bouncing and breaking objects might seem like two separate sound scenarios, but their behavioural similarities are close enough to consider them from the the same perspective. On the basis of this concept, I developed tangible techniques for the handling of musical material, whereas the previous concepts (i.e., Air and the Superman; Sound as music) provided models and objectives aimed at bringing listeners to a specific perceptual state. The next two sections describe the implementation of bouncing and breaking as models. This is followed by a description of mapping objectives, based on the attributes of bouncing and breaking.

3.4.1. Bouncing

The predominant model in *CAS* is the representation of leaping and its subsequent reiterations.[27] If the initial action is a leap, then the trajectory of the consequent action is downward – a return to earth. In this way, the leap is both physical/corporeal (i.e., bouncing, hopping, bobbing, skipping, ricocheting, conveying upsurge and spasm) as well as aural (i.e., ascending/ descending pitch or timbre described as cyclic, centric, undulating or forming a parabola). Consequently, the leap motivated my interest in mapping musical material to an exponentially decaying sinusoid (Example 3-1), whose shape



Example 3-1. Exponentially decaying sinusoid.

[27] The reader should not forget the description of leaping given in Air and the Superman (**3.2**).

calls to mind the loss of inertia of a bouncing object. Mapping such a shape to musical gestures, as well as sound synthesis parameters, is relatively straightforward. The temporal structure of a bouncing object is intuitively understood by the ear and is easily produced with acoustic instruments. For instance, every musician is asked to perform the following aleatoric bouncing gesture (Example 3-2) at one time or the other. A linear dependency of decay

Example 3-2. Bouncing gesture.

time over frequency – linked to such things as the material of a bouncing object and frictional forces at play – is incorporated into this gesture. Furthermore, a gradual domination of higher frequencies over lower frequencies – reflected in material attributes of both resonance and interaction properties – are absorbed into the bouncing gesture. Dense temporal groupings, leading to ringing, or fast pseudo-periodic machine-like sounds, may also be assembled using multiple instrumental voices.

3.4.2. Breaking

The predominant feature separating a perception of breaking from bouncing resides in temporal structure; breaking can thus be viewed as a variation of bouncing. Studies have indicated that the layering of collision sounds is normally identified as breaking or bouncing depending on their homogeneity and the regularity of density of their temporal distribution (Warren and Verbrugge, 1984; Rath and Fontana, 2003). If accompanied by a strong onset (i.e., a brief noise impulse) the sensation of breaking is more pronounced. Similar to conveying a perception of bouncing, the sonic attributes of a breaking event may be produced and mapped to musical gestures, with a thoughtful approach to orchestration. In *CAS*, however, the instruments that best imitate the qualities of breaking objects are the keyboard and the t-sticks (i.e., the digital instruments). Moreover, the parameters of the synthesis engine of each DMI allow for the potential to create unrealistic or imaginary breaking sounds.

3.4.3. Mapping objectives

As described above, the concept of bouncing and breaking prompted a mapping objective: mapping musical material to an exponentially decaying sinusoid due to the resemblance between the contour of the sinusoid and the temporal structure of a bouncing object coming to rest (**3.4.1. Bouncing**). The implementation of this objective in relation to easily produced musical gestures has also been mentioned. The following additional mapping objectives constitute the key formative principles of the composition.

1. Period of a sinusoid mapped to large and small scale structure (Chapter 4)
2. Temporal structure and behavioural characteristics of a sinusoid mapped to DMI sounds and spectral space (Chapter 5)
3. Amplitude of a sinusoid mapped to pitch space (Chapter 6)
4. Contour of a sinusoid mapped to melodic motion and motivic conception (Chapter 7)
5. Zero-crossings[28] of a sinusoid mapped to event onset time, resulting in rhythmic structure (Chapter 8)

3.5. Musical excerpts

The early stages of composing a new work often entail the gathering of ideas that may come from a wide range of concepts, disciplines and influences. A composer might say that the sorting out of these ideas is inherent to the compositional process; composing is a repetitive process of distillation during which the extracted substance is increasingly purified with each recurrence. In the beginning, eleven musical excerpts, drawn from other composers' work, informed my composing of *CAS*. I chose the excerpts because of their ability to evoke in me the impression of bouncing,

[28] Zero-crossings along a sinusoid waveform correspond to points at which the reading of air pressure (i.e., amplitude) is equal to the ambient air pressure value. These point are typically represented by a measurement of 0.0 on a relative scale between 1.0 and -1.0.

metaphorically speaking. They were not selected with any intention to parody or replicate them. Making any sort of commentary on either the borrowed composition or the composer was not part of any idea to model features of *CAS* after musical excerpts. Moreover, I did not wish to suggest that the refashioning of already existent material was a novel concept in my piece.[29] Rationalising the selection of all eleven models would serve no pertinent function in this document, seeing how most of their remnants became supplanted – vaporised away during the distillation process. Nevertheless, the following three sections discuss how traces of the musical excerpts served as models for developing the central formative principles of my composition.[30]

3.5.1. Section duration values

My initial motivation for selecting musical excerpts concerned structure. The excerpts were manipulated as objects (i.e., found sound objects), placed sequentially in different arrangements. Each distribution brought with it a distinct flow of musical material and more importantly, exact duration values. After several attempts at different arrangements, an order that best conformed to an amplitude decaying, frequency increasing sinusoid (Example 3-1, page 36) was chosen. That is to say, the musical excerpts were organised in such a fashion that their duration values resembled the period values of the sine wave. In this way, the arrangement of excerpts served as an initial model for compositional structure. Chapter 4 details further manipulations of this structure (**4.3. Formative principles**).

3.5.2. Musical gesture models

Two electronic music excerpts critically affected the shaping of large and small-scale structure, object and motif – all of which participate in conveying musical gesture. In *CAS*, the two electronic excerpts are models for

[29] We can return in time to the Renaissance, at least, and this period's use of secular love songs as *cantus firmi* in parody masses.

[30] For other key principles, refer to Bouncing and breaking (**3.4**).

primary gestures such as convergence and divergence and their associated motion and growth processes such as ascent, descent and plane, as well as less related activity such as agglomeration, dissipation and movement from continuity to discontinuity.

The first model is a one-minute excerpt from Jean-Claude Risset's *Songes* (1979).[31] It depicts a lengthy extended glide to an apex. It progresses from low to high through a passage of bell-like tones encompassing a large spectral space. More importantly, there is an intriguing motion and growth process at work. Layers are seemingly added to one another in an endogenous manner as if generated by the subconscious of the listener, figuratively speaking. They appropriately evoke the dream analogy suggested by the title. As layers appear, they persist for a relatively lengthy duration while newer layers seemingly appear from within the sound mass, before being absorbed into the global gesture of the passage. The effect is a combination of agglomeration and dissipation. In other words, the complete gesture overwhelmingly alludes to a thickening of spectral space until nearing the end, when a convergence occurs on a high, pure tone. The effect is perhaps akin to being smothered, only to be tugged into consciousness at the very end.

A part of Aphex Twin's *Bacephalus Bouncing Ball*, from the *Come to Daddy* compilation, is the second electronic music excerpt (James, 1997). The work is an example of late 1990s electronica – referring to a form of mainstream or popular electronic music designed for a wide range of uses, including dancing, foreground listening and background sound. Aphex Twin produces a type of music described in the vernacular as 'acid house' or 'acid techno'. Out of my eleven initial models, *Bacephalus Bouncing Ball* comes closest to evoking the perception of bouncing. There is a strong suggestion of sampling/recording of real-world bouncing objects. Two thirds of the way through the piece (approximately 4:30), the treatment of the bouncing gesture

[31] From approximately 5:40 to 6:40.

begins to diverge from earlier static repetitions. Onsets take on the quality of dense temporal groupings, which gradually work into a perception of prolonged tone, albeit granular and very brief – the beat must go on. In turn, the temporal grouping of onsets is retrograded, effectively toying with a perception of onset versus termination. That is, the reversing of a temporal grouping has a particularly strong terminative profile. Another interesting feature is the use of different tempi, albeit extremely short-lived. One wonders if Aphex Twin (also known as Richard James), following his encounter with Karlheinz Stockhausen in 1995, assumed a new outlook on repetitive rhythm.[32] The final third of *Bacephalus Bouncing Ball* reveals a slow deterioration of the bouncing gesture through the means described above. For instance, bouncing objects seem to have less and less to do with the continuum that drives the first two thirds of the work. There is still no shortage of repetition in this final section. Nonetheless, the overall gesture of a decomposing and discontinuous bouncing object is what stands out, and this informed my thoughts on musical gesture.

3.5.3. Motif and harmony model

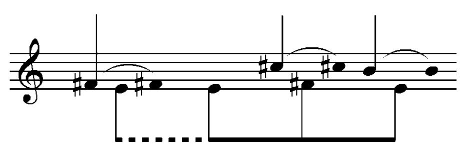
To me, the music of Maurice Ravel (1875-1937) often evokes a perception of bouncing. His compositions are not exclusively shaped in the form of a bounce or a leap. Nevertheless the vibrant rise and fall one might associate with the contours of a bouncing object are relatively constant in the composer's *œuvre*. *La Valse* (1919-20) is the quintessential example. I was drawn, however, to the presence of ostinati and the sensation of undulation in the *Prélude* of Ravel's *Le Tombeau de Couperin* for piano (1914-17). Despite a widespread selection of motivic repetition and smooth wave-like motion in the *Prélude*, I only chose mm. 14-7 (see Example 3-3, below) as a model while I composed *CAS*. These measures are especially present in the central

[32] Stockhausen stated that Richard James would discontinue repetition, in favour of changing tempi and changing rhythms, after a study of the German composer's *Gesang der Jünglinge.* (Witts, 1996)

Example 3-3. Ravel's *Le Tombeau de Couperin*, *Prélude* (mm. 14-7).

seventh section of my piece*,* which aptly features the MIDI keyboard player as soloist. I was particularly attracted to two features of the four-measure musical excerpt: motivic organisation and harmonic progression. In the following paragraphs, I will first discuss motif, before I turn to harmony.

The *turn* is the foremost motif in the *Prélude*, and the right hand of the first measure of my chosen excerpt (mm. 14) brilliantly demonstrates its presence in the organisation of numerous note groupings. I isolate the right hand motion in Example 3-4. While the right hand ripples along, the left hand music is almost entirely dominated by linear chromaticism (i.e., chromatic scale). The lowest voice begins on a B-natural (mm. 14) and completes its linear descent on an A-natural (mm. 17). A careful examination of inner voices in both the left and right hands – look at the progression formulated by conjoining the lower neighbour tones of the right hand – uncovers additional linear and chromatic motion. Similar to the descending bass line, all other lines have A-natural as their tone of resolution. Consequently, a sense of convergence upon A-natural occurs in mm. 17; even though the coincidence encompasses a range of two octaves and A-natural is never played in both hands at the same time.[33] In this brief description of mm. 14-7 of Ravel's *Prélude*, I am highlighting three motivic features: (1) the *turn* or alternating



Example 3-4. Conjunct and disjunct neighbour tone motion from the right hand of Ravel's *Prélude* (mm. 14).

[33] The importance of A-natural in mm. 17 is reinforced by the first chord of mm. 18, an A minor triad.

notes, (2) scalar motion and (3) large-scale movement toward a single pitch through a procedure that I am calling convergence. Chapter 7 reveals the importance of these attributes as models for my own motivic development in *CAS* (**7.3. Three essential motifs**).

The harmonic motion of mm. 14-7 is rich in chromaticism, moving through numerous passing chords and instances of tonicization from the V of E minor (mm. 14) – E minor is the suggested starting tonality, although the work ends in G major – to an A minor chord (mm. 18), which appears to play a submediant role (VI of C major). We have a hint of C major at the start of mm. 15; however, its main occurrence is at mm. 22. While completing the harmonic analysis of this passage, it occurred to me that the elements of chromaticism and tonicization, accentuated by a potent use of the 7th, 9th and 13th, and diminished 5th, might allow the entire progression to repeat in perpetuity. For example, mm. 14-7 (beginning on B major) are, in fact, precisely transposed up a minor 7th, resulting in mm. 18-21 (beginning on A minor). For my idea of *in perpetuity* to come true, mm. 22 would have to begin on G major or minor. A triad, or rather, a dominant 7th chord on G does occur in mm. 21. However, Ravel uses the chord as a dominant preparation for the arrival of C major, in mm. 22, thus he only executes the complete progression two times. Section 7 (mm. 315-56) of *CAS* illustrates my own use of the harmonic progression, which is also heard only twice, despite my intuition of Ravel's harmonies as an endless cycle. Refer to the explanation of *Keyboard pitch space* in Chapter 6 (**6.3)** for a further discussion about this motif and harmony model.

3.6. Summary

In this chapter, I discussed the significant concepts and corresponding models that influenced my composition. For instance, the metaphorical depiction of Air and the Superman, the coming together of psychophysics and environmental sound, bouncing and breaking sound scenarios, as well as musical excerpts of existent music were presented in this chapter in relation to the musical material of *CAS*. Furthermore, I illustrated how these models generated precise objectives that assisted me in laying down the foundation on which, for example, the formative principles of structure and motif could be derived.

4. Chapter 4 – Structure and form

4.1. Introduction

In this chapter, I first give a rundown of the large-scale structure in *Catching Air and the Superman*. Second, I discuss the formative principles of structure and third, I explain the structural segmentation and form of the piece.

4.2. Large-scale structure

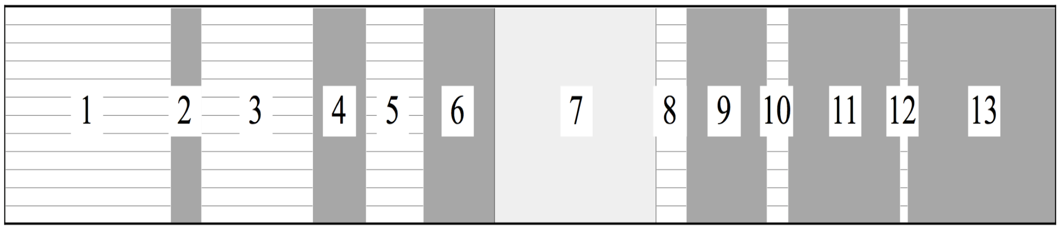
4.2.1. A description of structure

Catching Air and the Superman is divided into thirteen sections of varying lengths (Example 4-1). In Example 4-1, the third column, entitled 'duration', does not account for the conductor's interpretation of *accelerandi* and *ritardandi*. The column, entitled 'central object', is discussed in Chapter 7

<table>
<tr><th>section number</th><th>measures</th><th>duration (sec)</th><th>central object</th><th>central instruments</th></tr>
<tr><td>1</td><td>1 - 102</td><td>142</td><td>chord</td><td>orchestra</td></tr>
<tr><td>2</td><td>103 - 118</td><td>25</td><td>sustain</td><td>t-sticks</td></tr>
<tr><td>3</td><td>119 - 184</td><td>96</td><td>chord</td><td>orchestra</td></tr>
<tr><td>4</td><td>185 - 209</td><td>42</td><td>sustain</td><td>t-sticks</td></tr>
<tr><td>5</td><td>210 - 241</td><td>49</td><td>chord</td><td rowspan="2">digital instruments</td></tr>
<tr><td>6</td><td>242 - 281</td><td>60</td><td rowspan="2">16th-note alternation</td></tr>
<tr><td>7</td><td>282 - 362</td><td>139</td><td>keyboard</td></tr>
<tr><td>8</td><td>363 - 379</td><td>22</td><td rowspan="3">chord</td><td>orchestra</td></tr>
<tr><td>9</td><td>380 - 423</td><td>70</td><td>keyboard, mallets</td></tr>
<tr><td>10</td><td>424 - 434</td><td>17</td><td>t-sticks</td></tr>
<tr><td>11</td><td>435 - 501</td><td>97</td><td>sustain</td><td>orchestra</td></tr>
<tr><td>12</td><td>502 - 504</td><td>5</td><td>chord</td><td>keyboard</td></tr>
<tr><td>13</td><td>505 - 587</td><td>126</td><td>sustain</td><td>tutti</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>refrain</td><td>588 - 591</td><td>10</td><td>16th-note alternation</td><td>keyboard</td></tr>
</table>

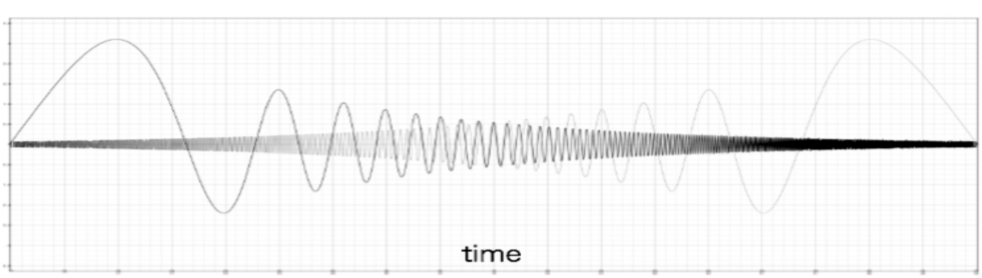
Example 4-1. Sectional information.

(**7.2. Two essential objects**). The specification of ‘orchestra’ in the last column refers to the acoustic instruments of the ensemble in addition to the keyboard with the exception of most of section 11. The t-sticks, on the other hand, are implicated in section 11.



Example 4-2. Proportional view of sections, excluding the ending four-measure refrain.

Generally speaking, sectional proportions follow a discernible pattern (Example 4-2). Sections 1 to 6 alternate long, short, long, short, short, long. The final six sections (8 to 13) are almost a reversal: short, long, short, long, short, long. The central seventh section is relatively long, rivalling the duration of both the first and thirteenth sections. Another gradation is perceived in Example 4-2 by omitting section 7 – the ending of section 6 abutting the beginning of section 8 – and focusing on every other segment. For instance, one notices a successive decrease in section length from left to right by allowing the eye to see every white (with horizontal lines) segment. Alternatively, an increase in length is detected by looking at every grey segment. Furthermore, the decreasing and increasing section lengths can be compared to the wavelength characteristics of two overlapping exponentially changing sinusoids, one sinusoid the retrograde of the other (the importance of sine waves was first mentioned in **3.4.1. Bouncing**). Example 4-3



Example 4-3. Two time-varying sinusoids, one the retrograde of the other.

illustrates two such waves. The darker shaded sinusoid is decreasing in amplitude and increasing in frequency, whereas the lighter illustrates an amplitude increase and frequency decrease. Comparing Example 4-2 (with section 7 omitted) to Example 4-3 allows one to detect similarities between the proportional aspects of the former and the wavelengths of the latter. Compare the white-lined segments of Example 4-2 to the darker sinusoid of Example 4-3. The lengths of the white-lined segments progress from long to short, just as the wavelengths of the darker sinusoid go from long to short. The significance of these sinusoids is further discussed in the next section.

4.3. Formative principles

Developing the structure of *CAS* first entailed assigning duration values to section lengths. For this task, I drew upon a list of values corresponding to two preliminary passages of original music I composed for MIDI keyboard in addition to a list of timings roughly drawn from my music models (**3.5.1. Section duration values**). This made thirteen items that corresponded to the thirteen sections of the composition (Example 4-1, page 45).

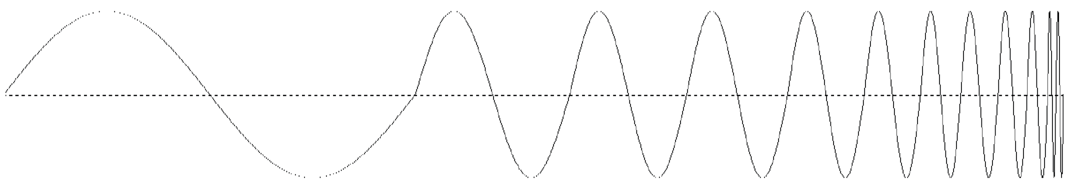
Second, initially mapping section duration to the period structure of an exponentially decaying, frequency increasing sinusoid was fundamental. To begin with, I used a twenty-minute sine wave that increased in frequency from 0.004 to 5.0 Hz.[34] 0.004 Hz roughly equals a sinusoid period of 228 seconds while 5.0 Hz is equivalent to a period of 0.2 seconds.[35] Next, I overlaid a second sinusoid that was an exact retrograde of the initial waveform (Example 4-3). The two overlapping sinusoids – with opposing contours – were better than one in that each gave a separate continuum of

[34] Simple graphing software was used to create the sinusoid.

[35] The upper limit of 5.0 Hz also corresponds to a Maelzel Metronome reading of 300 beats *per* minute, which is slightly faster than the 8th-note tempo of a viola and violoncello passage (containing pizzicato quadruple stops) in Béla Bartók's *Concerto for Orchestra*, *Finale*. The same playing technique is found in *Catching Air and the Superman*, thus the technique and its relative tempo became a rough measurement for both maximum sine wave frequency and global tempo in my composition.

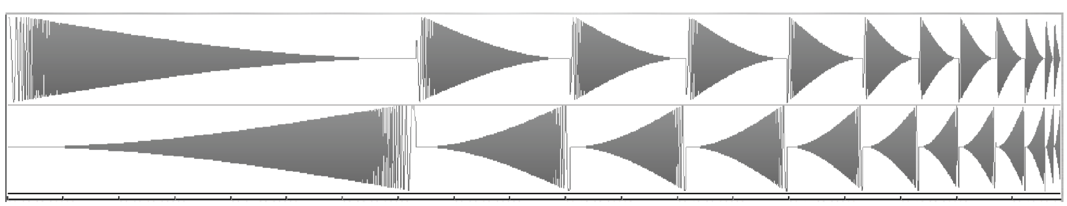
values for mapping amplitude to pitch space (**6.2.2. Amplitude mapping**) and inspiring a bi-rhythmic treatment of material (**8.3. Overview of grids and sequences**). The remaining steps, given below, describe the working-out of the final structure.

1. I reduced the initial twenty-minute sinusoid to only twelve wavelengths in an effort to establish a framework for mapping the duration values of my music models to period structure (Example 4-4). The twenty-minute duration and frequency continuum were maintained. In this way, the lengths of most of my music models could be roughly matched to an exact wavelength.



Example 4-4. Twelve wavelengths of a frequency increasing sine wave.

2. Replicas of the original overlapping sinusoids (Example 4-3, page 46) were embedded within each of the twelve wavelengths (Example 4-5). This step required scaling or shortening the duration of the original sine waves, but leaving amplitude and minimum and maximum frequencies untouched. For example, the frequency range of 0.004 to 5.0 Hz was preserved in the scaled waveforms.



Example 4-5. Sequence of time-scaled sinusoids forming twelve sections.

3. The twelve wavelengths were cut, spliced and arranged in an order that reflected the lengths of the eleven music models and two original music passages while at the same time conveying a sense of long, short, long, etc., mentioned in the previous section (**4.2.1. A description of structure**). Consequently, the result produced thirteen distinct sections, each section possessing the characteristics of the overlapping sinusoids in part or in whole. For example, the first segment of Example 4-5, which is approximately one third of the entire graphic, was cut, forming sections 1, 3, 6 and 9 of the eventual structure.

4. The final step firstly entailed dividing each of the thirteen main sections into smaller segments and secondly, subdividing these segments into even smaller units.

This final process duplicated, on the one hand, the earlier development of replicating sinusoids within each wavelength of a larger waveform – a self-replicating generative approach. On the other hand, the subdividing of subdivisions was a unique outcome of mapping zero-crossing and amplitude values to rhythm and pitch space while freely composing the central section of the composition (section 7).

4.4. Segmenting large-scale structure

The keyboard music of section 7 was the first passage to be completely realised while composing *CAS.* As a consequence, it became the model for segmenting many of the other main sections of the work. A description of section 7 is placed first in this section. Afterward, I work from the inside to the outside of the composition by explaining the inner parts of the piece, followed by the outer sections.

4.4.1. Section 7 (mm. 282-362)

The middle section of *CAS* acts as the structural heart or core of the work. It is placed in seventh position, with six sections coming both before and after, in order to illustrate its importance. On the one hand, it is united with the rest of the composition by object and motif, as well as general structural attributes. On the other hand, section 7 is set apart due to its harmonic allusions (i.e., triadic harmonic progressions), orchestration and the predominance of the solo keyboardist.

Section 7 consists of five segments, each subdivided into smaller units (see Example 4-6, below). Segments 1 to 3 are each divided into two units, segment 4 into three. A two-measure fifth segment is suggested, beginning at mm. 361; however, it is quickly 'interrupted' by, or elided with, section 8. Motivic characteristics are the principal determiners in unit or phrase segmentation. In some cases, the word 'unit' (used as a neutral term, meaning

segment	unit/ phrase	measures	beats (measured in 8th-notes)	opening motif	opening sonority
1	1	282 - 293	48 + 48	16-note alternation	F, F-sharp
	2	294 - 297	48	scales and convergence	
			TOTAL: 144		
2	1	298 - 309	48 + 42	16-note alternation	A-sharp, B
	2	310 - 314	54	scales	
			TOTAL: 144		
3	1	315 - 328	56 + 56	16-note alternation	A major/ minor
	2	329 - 334	48	divergence	
			TOTAL: 160		
4	1	335 - 346	95	16-note alternation	G major / minor
	2	347 - 356	71	scales	
	3	357 - 360	39	16-note alternation	C, D-flat
			TOTAL: 205		
5	1 interrupted	361 - 362	14	16-note alternation	D-sharp, D

Example 4-6. Section 7.

a subdivision) is more applicable than ‘phrase’ (meaning musical phrase), and vice versa. For instance, the 16th-note alternation of the first unit of segment 1 (mm. 282-93), which is introduced on the last two beats of mm. 281, is generally restricted in register and contains idiosyncratic breaks or hick-ups as a result of grace note ornamentation and 8th-note rests. A performer could interpret the break points as indicating phrase structure. Nonetheless, mm. 282-93 is considered a unit in my analysis. The second unit/phrase (mm. 294-97), however, is more characteristic of a musical phrase. Its linearity shapes a passage that suggests high and low or beginning and ending points. Moreover, the constant stream of notes in addition to a sense of repeated convergence upon B-flat create a perception of one lengthy musical phrase. For an analytical reduction of the passage, refer to Example 7-7 on page 98.

Divergence and convergence are significant motivic characteristics in *CAS* and are discussed alongside the 'opening motifs' of Example 4-6 (fifth column) in Chapter 7 (**7.3. Three essential motifs**). The 'opening sonority' (last column) is dealt with in Chapter 6 (**6. Pitch space and harmony**). For the moment, the reader is reminded that indicated sonorities are approximate, meaning that the perceived frequency may be microtonally higher or lower, or may be heard as an attenuated pitch cluster centred around the specified sonority. Furthermore, the indicated pitch/harmony may not be evident in the notated keyboard part. The keyboard sounds microtonally higher than written due to the timbral qualities of its synthesised 'voice'.

The fourth column, concerning the number of 8th-note beats *per* unit, indicates that the first unit of segments 1, 2 and 3 is roughly twice the size of their second unit (i.e. 2 : 1 ratio). This is exactly the case for segment 1, whereas the 2 : 1 ratio becomes more distorted in the following two sections and completely obliterated in segment 4. While composing section 7 each segment was initially divided into 3 equal lengths in a very mechanical and objective fashion. Once the music began taking its eventual form, structural proportions were modified in order to accommodate the ebb and flow of musical idea.

An overall idea in section 7 – as with the entire composition – is the gradual intensification of materials, broadly speaking. The misbalancing of section, segment and unit length is one way the intensification of materials can manifest itself. A perception of compression within the form is created, for example, near the end of section 7 (i.e., during segment 4). The first two units of segment 4 (mm. 335-56) are familiar, firstly starting with the 16th-note alternation motif and secondly presenting descending/ascending linear scales (refer to **7.3. Three essential motifs**). In this way, the first two units of segment 4 parallel previous segments in their use of motif, but not in length. The expected 2 : 1 ratio is replaced by an approximate 4 : 3 distribution (i.e., 95 : 71). Next, the 16th-note alternation motif returns in unit 3 (beginning at mm. 357), albeit very brief. The opening D-flat/C-natural alternation only lasts three 8th-notes before starting to distort. The D-flat to C-natural movement quickly gives way to a recurring downward contour that eventually descends onto the starting pitch classes (i.e., D-flat and C-natural) one octave lower at mm. 361, which marks the start of segment 5. Unit 3 of segment 4 is, therefore, shorter than any other unit that comes before it. In this way, it is a structural abbreviation of all preceding segments within a duration of 39 8th-note beats, played *accelerando*.

4.4.2. Inner sections (4-6/8-10)

Six inner sections surround the central seventh section, three before (i.e., sections 4, 5, 6) and three after (i.e., sections 8, 9, 10). These inner passages are of different lengths and are perceived as single phrases or units (Example 4-7). Generally speaking, their main structural distinctions, other than their being perceived as single units, are attributed to: (1) textural simplicity, with the exception of section 8; (2) a prevalence of inharmonic percussive timbre; (3) figurative emulations of bouncing objects.

<table>
<tr><th>section</th><th>measures</th><th>beats (in 8th-notes)</th><th>object</th><th>central DMI</th><th>opening sonority</th></tr>
<tr><td>4</td><td>185 - 209</td><td>200</td><td>sustain, chord</td><td>t-sticks</td><td>F-sharp, percussive</td></tr>
<tr><td>5</td><td>210 - 241</td><td>235</td><td rowspan="2">chord, 16th-notes</td><td rowspan="2">t-sticks and keyboard</td><td rowspan="2">inharmonic, percussive</td></tr>
<tr><td>6</td><td>242 - 281</td><td>288</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>363 - 379 interrupted</td><td>106</td><td>chord</td><td>keyboard</td><td>G, percussive</td></tr>
<tr><td>9</td><td>380 - 423</td><td>335</td><td>chord, sustain</td><td>keyboard</td><td>inharmonic, percussive, F-sharp (mm. 391)</td></tr>
<tr><td>10</td><td>424 - 434</td><td>82</td><td>chord</td><td>t-sticks</td><td>inharmonic, percussive</td></tr>
</table>

Example 4-7. Inner sections.

Firstly concerning texture, the DMIs, in their role as either a digital instrumental trio (sections 5 and 6) or duo (section 10), prevail in three out of the six inner sections. Alternatively, instruments from the acoustic instrument ensemble dominate section 8; however, in sections 4 and 9 they are sparingly and reservedly used for the most part. The acoustic instrumentation and orchestration of sections 4 and 9 are almost identical, at least for the first twenty-five measures. Section 9 introduces new material for the vibraphone and marimba and extends the texture that originated in section 4. In this regard, the listener may perceive sections 4 and 9 as having a structure resemblance.

Secondly, specific aspects of timbre are shared across all inner sections. Timbral uniformity is weighted in favour of the inharmonic sound quality of the DMI 'voices'. For instance, the keyboard timbre in sections 5 (e.g., beginning with a single chord at mm. 213) and 9 (mm. 380-423) are extremely similar – and identical from mm. 403, onward. The same is true for the t-stick 2 timbre in sections 4 and 10. These correspondences suggest structural connections between sections 5 and 9, as well as 4 and 10.

Emulating bouncing objects is a third characteristic that is particularly present in the inner sections. For instance, this type of emulation is successful with the DMIs due to the behavioural aspects of their sounds. In addition, a bouncing object profile (i.e., descending/ascending, cyclic, centric and undulating) is easily mapped to rhythm and pitch space; sections 6 and 8 are collaborators in this respect. Section 6 for DMI trio (beginning at mm. 259) emulates a decelerating bouncing object. In section 8 (mm. 363-79), individual orchestral instruments, except for the t-sticks and percussion, join together forming a composite rhythmic gesture that begins by inversely imitating section 6. That is, they emulate an accelerating bouncing object in an erratic fashion as if bouncing an asymmetrical object that reaches its zenith around mm. 373, then decelerates into section 9.

4.4.3. Outer sections (1-3/11-13) and refrain

The outer parts of *CAS* concern sections 1, 2 and 3, as well as 11, 12, 13 and the ending refrain (see Example 4-8, below). These sections are grouped together because of their continuities. Sections 1, 3 and 11, 13 are all multi-segmented, each pair separated by a one-segment section (i.e., sections 2 and 12). The 'central object' and 'central DMI' (respectively columns six and seven of Example 4-8) alternate from section to section. For instance, the objects and DMI of 1, 2 and 3 alternate: chord/keyboard, sustain/t-sticks, chord/keyboard. Sections 11, 12 and 13 alternate: sustain/t-sticks, chord/keyboard, sustain/t-sticks. The introduction of an F-sharp sonority, which is central to a large portion of the latter outer sections, first occurs in the second half of section 3 in addition to section 4 (refer to **4.4.2. Inner sections**).

The central section and the outer parts of my composition share continuities in addition to the outer movements having similarities among themselves. Both structural and motivic aspects of the outer sections take their cues from section 7. For example, the general tendency in section 7 to begin with more or less balanced unit/phrase duration and end with less equal proportions holds true in both a section by section analysis and a study of the total composition. The first three units of segment 1, section 1, roughly have the same number of 8th-notes. If one totals the first unit (17 + 110), the sequence of total 8th-note beats is 127, 146, 134 – a maximum difference of nineteen beats between the highest and lowest values, which amounts to just under, say, two and a half $\frac{4}{4}$ measures. This segment is well-balanced when compared with the distribution of beats in segment 2 of section 1. Furthermore, the first three units of the piece are particularly well-proportioned when compared with the balancing of unit duration in section 13, although relatively equalised proportions return in the last unit of section 13, depending on the conductor's interpretation of the fermata at mm. 585.

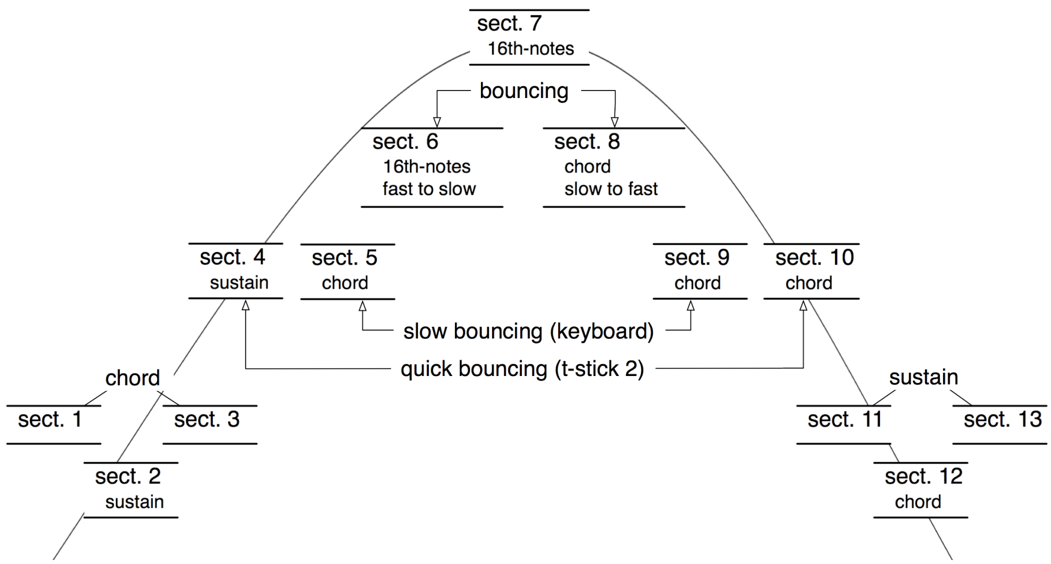
section	segment	unit/ phrase	measures	beats (in 8th-notes)	central object	central DMI	opening sonority
1	1	1	1 - 17	17 + 110	chord	keyboard	G#, A vibraphone and strings (mm. 3)
		2	18 - 40	146			
		3	41 - 59	134			
	2	1	60 - 75	103			D#, E vibraphone and strings
		2	76 - 99	147			
		3 interrupted	100 - 102	24			
2	1	1	103 - 118	120	sustain	t-sticks	G#
3	1	1	119 - 129	87	chord	keyboard	A#, B vibraphone and strings
		2	130 - 142	90			
	2	1	143 - 166	180			F-sharp vibraphone (mm. 149)
		2 interrupted	167 - 184	106			
11	1	1	435 - 463	196	sustain	t-sticks	F-sharp, G
	2	1	464 - 473	74			F, F-sharp
		2	474 - 484	66			
	3	1 interrupted	485 - 501	128			F, F-sharp
12	1	1	502 - 504	22	chord	keyboard	inharmonic
13	1	1	505 - 518	108	sustain	t-sticks	F-sharp, G
		2	519 - 521	24			section 1 harmony (winds)
	2	1	522 - 526	40			
		2	527 - 530	28			
	3	1	531 - 540	82			
	4	1	541 - 563	156			
	5	1	564 - 575	85			
		2	576 - 587	82			
refrain	1	1	588 - 591	48	16th-notes	keyboard	F, F-sharp

Example 4-8. Outer sections.

The word ‘interrupted’ occasionally appears in Example 4-8, as well as in Example 4-7 (page 52). I used it first in a description of the final segment of section 7 (Example 4-6, page 50). The interrupted or elided passage is another similarity between the central part of *CAS* and the surrounding sections. An interruption is created when an event is perceived as having both a salient terminative quality and a strong onset. The robust inharmonic keyboard chord, often accompanied by an forceful *tutti* in the orchestra, exemplifies the interruption, especially because the keyboard frequently lingers on after a co-ordinated punctuation. Measures 185, 380 and the end of 501 are particularly strong examples of this articulation in structure and form. A listener might perceive the first 142 seconds (i.e., section 1) of the composition as indicative of dramatic interruptions in the form, primarily through a series of weighty keyboard chords (mm. 2 to 102). This passage actually guarantees the primacy of the chord not only as a mechanism for articulating form, but also as foreground material that consequently allows for variations on a ‘chord-object’ (**7.2.1. Chord-object**).

4.5. A description of form

CAS is symmetrically formed and arch-shaped (see Example 4-9, below), although there is good reason to describe its form as a sequence of alternating passages. The alternation of long, short, long, etc. section duration was made clear near the beginning of this chapter. Furthermore, there was a suggestion of linearity by focussing on every other part of the piece (**4.2.1. A description of structure**). Nevertheless, the methods of subdividing and organising the main sections and their internal segments, which I discuss above (**4.4. Segmenting large-scale structure**), upholds the description of form as arch-shaped. Furthermore, the reader will notice correspondences in my use of the terms ‘sustain’, ‘chord’ and ‘16th-notes’ in Example 4-9. These words represent characteristics of objects in *CAS*, and are part of my dialogue in Chapter 7 (**7.2. Two essential objects**).



Example 4-9. Form.

4.6. Summary

Composition structure and form were the topics of this chapter. I discussed the importance of reshaping an exponentially decaying, frequency increasing sinusoid in determining section proportions. I then detailed the structure of *CAS*, working from the inside of the piece (i.e., section 7) to the outer sections. The chapter concluded with an illustration of compositional form.

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5. Chapter 5 – Spectral space and electroacoustic properties

5.1. Introduction

While the initial function of the keyboard instrument (representing 'the Superman') was to provide a series of sonorities from which harmony could be conceived (**6.3. Keyboard pitch space**), its raw sound also plays a significant role in conveying an electroacoustic sound world beyond what is possible with acoustic instruments, especially through its capacity to evoke an impression of real-world bouncing objects. In contrast with the keyboard, the two soprano t-sticks (representing 'Air') fortify certain spectromorphological phenomena that can not be produced by acoustic instruments.[36] The central topic of this chapter concerns a description of electroacoustic spectral space in *Catching Air and the Superman* through an examination of:

1. behavioural patterns (e.g., vertical and horizontal temporality)
2. texture motion (e.g., streaming)
3. directional motion and growth (e.g., undulating movement)

Following an explanation of formative principles, an account of keyboard, t-stick and orchestral spectral space is given.

5.2. Formative principles

5.2.1. Sound synthesis

Both compositional spectral space and the development of sounds for each DMI emerged from research into the sound design of real-time impact models and the emulation of the structural and transformational attributes of these models. Impact models often include acoustic sub-events that allow us to identify scenarios such as bouncing, breaking and rolling. These sub-events, along with their structural (i.e., size, shape, mass, elasticity, surface properties) and transformational (i.e., velocities, forces, position of interaction

[36] The terminology surrounding spectromorphological phenomena in this document originates in Denis Smalley's *Spectromorphology: explaining sound-shapes* (1997).

points) attributes, were imitated using Apple's Sculpture[37] software based on physical modelling synthesis.[38] For instance, this synthesis algorithm supplied a selection of object materials such as wood, glass, metal or nylon. Moreover, it allowed for a variety of excitation methods (e.g., strike, blow or bow) and the positioning of an excitation point (i.e., contact or interaction points along the surface of the physical model). The following three steps outline the procedure for creating the sound of the DMIs, and consequently, the electroacoustic spectral space in *CAS*.

1. Six short identifiable 'source sounds' were synthesised. The source sounds had easily perceivable and clear onset and termination attributes. Furthermore, the sounds' sustain or continuant segment was relatively consistent without a complex textured interior.

Example 5-1. Six source sounds.

2. A limited number of variants (i.e., five to ten) of each source sound were created by incrementally modulating the physical modelling parameters. Similarities among the variants and their respective source sound were maintained along two directions. One set of variants maintained the structural attributes of the source sound while the other group of variants had altered structural properties but retained a transformational resemblance to the source sound. Generally speaking, variants are perceived as more complex than the source sounds.

Example 5-2. One source sound followed by variants. Structural properties are maintained.

Example 5-3. One source sound followed by variants. Transformational properties are maintained.

3. Morph or modulation 'paths' among a source sound and its variants were implemented using the synthesis software. An input device (i.e., t-stick or keyboard) allowed me to initiate a sound anywhere along a

[37] Sculpture is the physical modelling module in Apple's Logic Pro, an integrated system for composing, producing and scoring music.

[38] A synthesis algorithm used to generate sounds that exhibit the acoustical properties of real-world objects. Synthesis parameters are couched in terms of the physical descriptors of the real-world objects being synthesised.

path, at which point the software interpolated the correct physical modelling data in real-time.

Example 5-4. Morphing among one source sound and its variants. Structural properties are maintained.

Example 5-5. Morphing among one source sound and its variants. Transformational properties are maintained.

5.3. Keyboard spectral space

The keyboard presents a broad and abundant spectral space that can be generally described as metallic and from a diverse range of metals. Its timbral regularity provides both a source of pitch material (**6.3. Keyboard pitch space**) and a consistent sense of ground in the work. In particular, the low frequency content of the keyboard spectrum and the strongly articulative nature of the instrument's sound anchor several sections of the composition and allow the instrument to be easily recognised even after a long absence. For instance, the keyboard is especially salient at its re-entry at mm. 493.

The instrument permeates the entire first half of the composition (mm. 1-281), with brief pauses in sections 2 (mm. 103-18) and 4 (mm. 185-209). Generally speaking, its spectral space covers an extremely wide frequency range and undergoes subtle timbral shifts that occur at section beginnings due to pedal changes.[39]

In section 3, rhythmic activity gradually increases, reaching its maximum agitation during a long *accelerando* (mm. 171-85), which also exhibits ever increasing polyphony within the keyboard part. During this passage, individual notes gradually form linear motion interspersed between chords. The spectral space of the reiterating keyboard chords in sections 1 and 3, therefore, radically transforms due to a break-down in vertical co-ordination (i.e., behavioural aspects). By the end of section 3 (mm. 184-5) the

[39] Strictly observing the pedalling indications is essential to achieving the correct keyboard timbre. Even the slightest delay in engaging/disengaging the pedals may result in a dramatically different sound colour. Refer to **Appendix B** – Digital instrument specifications and performance notes for an explanation of keyboard pedalling.

keyboard is neither less articulate nor less spectrally broad. However, a sense of causality or expectation is heightened by the loss of vertical synchronisation and rapidly varying spectral space in combination with the rhythmic and tempo intensification. In addition, an aural sound agglomeration exhibited by the keyboard intensifies the relationship between cause and effect. Agglomeration is associated with the motivic aspects of divergence and convergence and describes the multi-directional growth pattern at play in the opening half of the composition.

The first 17 measures of section 6 (mm. 242-58) also exemplify multi-directional motion and growth (Example 5-6) and vaguely call to mind the motion and growth processes of Risset's acousmatique piece *Songes* discussed in Chapter 3 (**3.5.2. Musical gesture models**). The keyboard part in section 6 features a long succession of rapid and metallic attacks that, on the one hand, dilate the overall spectral space, and on the other hand, create a feeling of convergence. This is in addition to the ascending right hand notes that are normally played as imperceptibly as possible.

Example 5-6. The first 17 measures of section 6 (mm. 242-58), keyboard only.

The remainder of section 6 (mm. 259-81) emulates a bouncing object that undulates between two distinct timbres, one articulated by a low frequency onset, the other a high onset. T-stick motion and growth patterns parallel the keyboard spectral space, although t-stick 2 shows signs of rhythmic independence as the passage progresses.

In section 7 (mm. 282-362), the sound spectrum of the keyboard is constrained with the aim of drawing out the specific harmonies of Ravel's *Prélude* (as I discuss in **6.3. Keyboard pitch space**). The section reveals a narrower keyboard spectral space at any one time than the previous sections; however, subtle timbre shifts consistently occur at the beginning of new segments similarly to sections 1 and 3. The acoustic instrument orchestration accentuates these shifts (described below in **5.5. Orchestral spectral space**).

The keyboard is relatively less active in the latter half of *CAS* (mm. 363-587). Furthermore, the instrument does not introduce any new foreground sound colour. It either temporarily revisits the spectral space of the first half or timbrally reinforces the acoustic instruments of the ensemble. For instance, section 9 (mm. 380-423) recapitulates the sound colour of sections 3 (mm. 119-84) and 5 (mm. 210-41) for the most part, whereas the right hand of the eight-measure passage beginning at mm. 493, near the end of section 11, leads to the solo of section 12 (mm. 502-04) and recalls the splashy keyboard timbre from the opening of the composition. A short while later, the ornamental right hand of section 13 (mm. 509-532) provides examples of the keyboard reinforcing the flute and piccolo. Moreover, the left hand complements the percussive roto toms pulse while at the same time alluding to the bass drum, which had a noticeable entrance in section 11 (mm. 473), but is absent from section 13.

5.4. T-stick spectral space

The t-sticks carve out a spectral space through different means from the keyboard. The breadth of their spectral spaces are as expansive as that of the keyboard, but their spectromorphological phenomena manifest in sustained continuous sound. That is, the t-sticks are capable of producing forceful percussion-like onsets similar to the keyboard; however, they predominantly initiate and sustain sound. Sustaining sound on the keyboard, on the other hand, is only possible through a continuous re-attacking of notes – following the normal piano performance paradigm – due to its decaying attack envelopes. The continuous sound colour of each DMI, including the keyboard, coincides with the point being accessed by the DMI along a morph path, previously described (**5.2.1. Sound synthesis**). Each position along a path generates different electroacoustic properties that alter aspects of spectral space. Moreover, the instruments' spectra are varied by sustaining a sound while moving along a morph path at the same time.

5.4.1. T-stick 1 spectral space

The sounds inhabiting the spectral space of t-stick 1 range from high pitched bowed or lightly tinkled bell sonorities (mm. 185) to heavily plucked electric bass drones (mm. 210). An assortment of sounds between these contrasting poles evoke both realistic and imaginary metallic sonorities. For example, the first seventeen measures of section 6 (mm. 242-58) and the first few measures following the climactic point of the composition (beginning at mm. 540) create a perception of small bouncing metallic balls. The measures following the climax quickly morph into an agglomeration where the metal balls swiftly and dramatically grow in mass and weight; this is one of the most challenging passages for t-stick 1.

The ability to modulate or evolve sound in a way that is not consistent with how sound naturally changes leads to a wealth of imaginary timbres on t-stick 1. In particular, spectrally dense and broad sustained inharmonic metallic sounds characterise the instrument's spectral space. We do not have any distinct frame of reference for sustained inharmonic metallic sounds like those produced by the t-stick in our acoustic environment, although the sounds of machines of all sorts may be described as steely, metallic and dominated by bass frequencies. Listeners may find some resemblance to bowed metal percussion instruments, but they probably will not perceive any likeness to other musical instruments such as the trumpet or other members of the brass family. In *CAS*, the sustained metallic 'voice' of t-stick 1 suggests imaginary excitations that could be described as continuously blowing on/through (section 2), or bowing on (section 4), metal plates of different sizes. A "well-tempered vacuum cleaner" may come to mind while listening to section 13 (mm. 505-40).

5.4.2. T-stick 2 spectral space

The sound of t-stick 2 creates a narrower spectral space than the sound of t-stick 1 and has two distinct sonorities that parallel the two different ways of playing the digital instrument. The first sonority evokes the timbral quality of wood wind instruments and is a result of finger or hand contact with the surface of the DMI. It especially shares the spectral attributes of the velvety lower range of the flute, if the flute were able to play *forte* in its lowest register and several octaves lower. In other words, t-stick 2 calls to mind the flute, but also extends the sound description of the acoustic instrument. Moreover, the spectral space of t-stick 2 ranges from mellow flute to bright airy tones that approach white noise or the rushing of air blown across the end of a glass bottle. For instance, section 11, beginning at mm. 435, is particularly illustrative of a bright, turbulent and airy tone gradually morphing into a rounder sound colour with a focussed frequency range. The spectral space of t-stick 2 transforms into a thin pure tone cluster by mm. 504, played *forte*.

Jabbing or thrusting gestures trigger the second t-stick 2 sonority, which resembles a range of percussion instruments from low pitched membranophones (e.g., bass drum) to piercing metallic idiophones (e.g., crotales). This second sonority goes a long way toward both maintaining a timbral balance with the percussive nature of the keyboard and also conveying the bouncing attributes of a real-world object. One jab approximates a 'one-off' bounce. That is, the jabbing sonority calls to mind a single rebound of a bouncing object. A series of well-controlled jabs, therefore, emulates consecutive rebounds. The jabbing sonority is often responsible for defining the extremes of the DMI's spectral space. For instance, the last twenty-three measures of section 6 (mm. 259-81) feature an alternation between upper and lower spectral space. Other examples are sections 10 and 13 in which lower frequencies are gradually attenuated, consequently leading to a rise in pitch. The ascending motion is especially salient in section 13 (mm. 573-88) because it accentuates the final convergence that leads into the concluding refrain.

5.4.3. T-stick spectromorphological phenomena

Example 5-7 (pages 68-9) contains graphical representations of t-stick spectral space for every section in which the t-sticks are heard, along with spectromorphological descriptors: behaviour, texture motion, motion and growth patterns. Generally speaking, spectromorphology (Smalley 1997) is concerned with the microscopic evolutions and large-scale structure of sound objects. It includes both terminology and concepts for describing the interaction between sounds and between sounds and listeners.

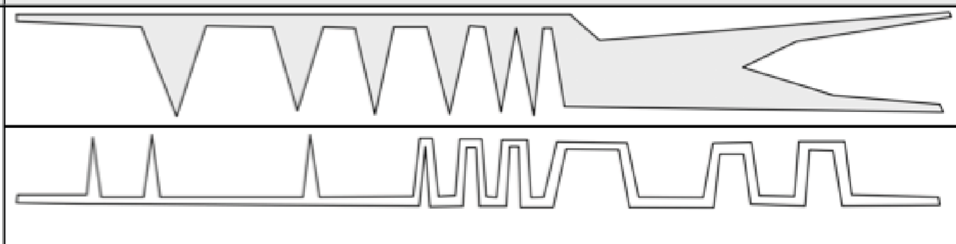
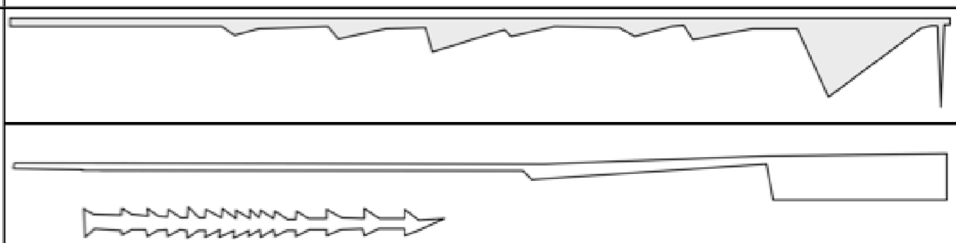
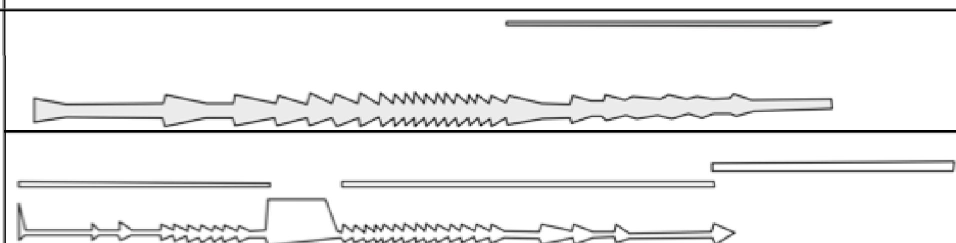
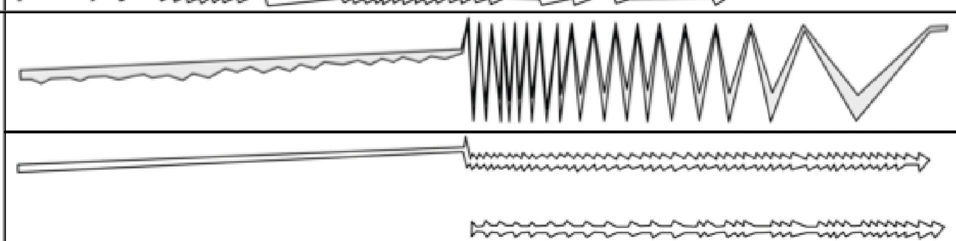
Glancing at the second column of Example 5-7 confirms the general widths of t-stick spectral space. The vertical axis of each frame of column two, in which each spectral space representation sits, roughly denotes the frequencies that are audible to the human ear. The lower edge of the frame corresponds to low frequencies and the upper edge, high frequencies. T-stick 1 consists in a broader frequency range than t-stick 2 on the whole. That is to say, at any one time, t-stick 1 produces a sound spread over a greater spectral range than t-stick 2. This does not indicate that the latter is incapable of playing extremely high or low; but rather, t-stick 2 sound is generally concentrated in a narrower range at any one time.

The behavioural indications (third column of Example 5-7) expand on the relationships among sounds produced by both t-sticks and especially apply to the vertical (indicated first) and horizontal (indicated second) organisation of events. In general, vertical synchronisation between the t-sticks improves over the course of the composition, whereas horizontal characteristics vary. The terminology in the third column should be self-explanatory except for the the words ‘pressured’ and ‘voluntary’ in relation to horizontal organisation. Pressured and voluntary represent opposite poles of a continuum describing the pressuring urgency (or lack of urgency) of one sound to yield to, or project into, the next. Attributes such as vertical co-ordination, motion trajectory and onset rate influence how one sound moves to the next. For example, an acceleration in onset rate (i.e., an accelerating horizontal presentation of sounds, each possessing its own distinctive onset) inevitably brings about termination, which might take the form of a maximum attack density or a sufficiently fast-paced tempo that provokes some sort of release into a new sound/texture.

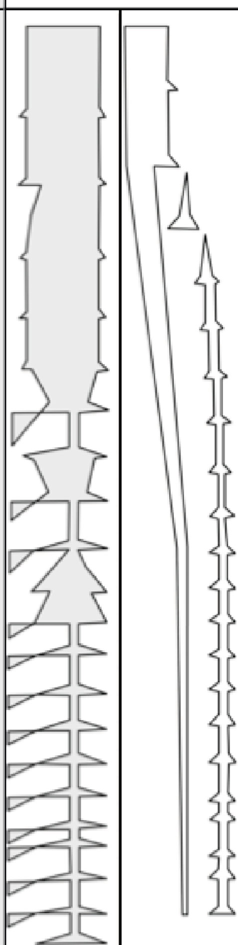
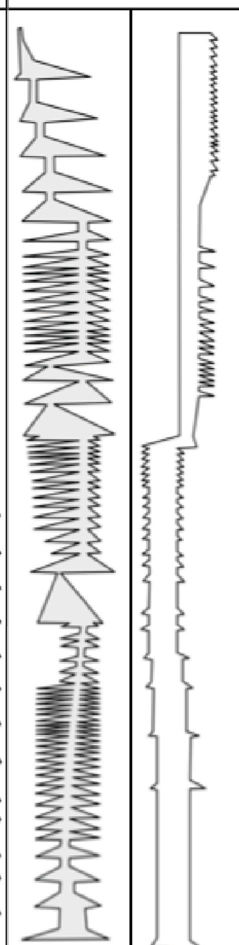
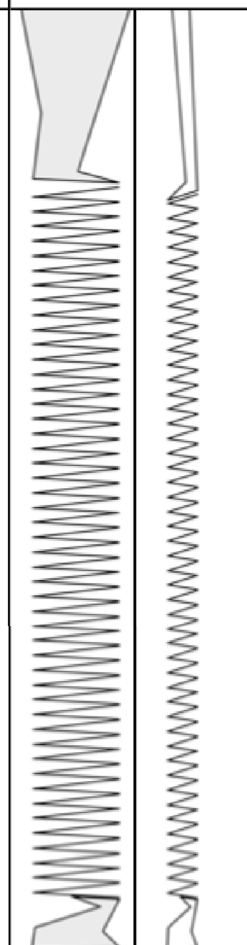
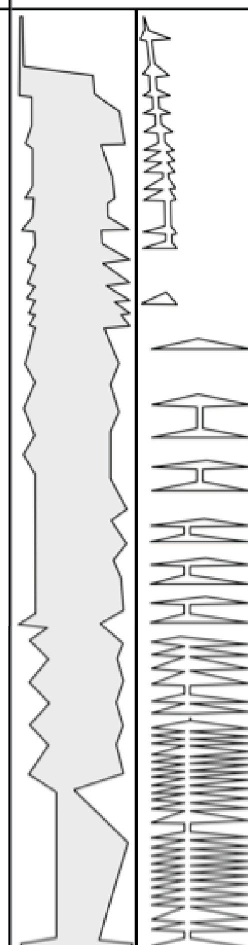
The yielding to a new sound occurs in section 2 (mm. 103-18) and is evident in the graphical representation of spectral space (Example 5-7). T-stick 1 specifically describes a 'composed' acceleration, which is achieved by simultaneously rotating the instrument and observing the dynamics notated in the score; this passage may remind the reader of a bouncing object coming to rest. The accelerating metallic 'voice' of t-stick 1 is particularly strident and turbulent until mm. 113, at which time the resulting sound evokes the apex and subsequent reverberation of a heavy metal object (e.g., a large tam-tam). The spectral space to t-stick 2 presents a similar acceleration to t-stick 1 space, although the acceleration pattern is less pronounced and not closely synchronised with t-stick 1, thus a loose vertical co-ordination is suggested.

Texture motion (fourth column of Example 5-7) concerns the collaboration of sounds working together to form spectromorphological structure (i.e., a composite shape of interacting sounds). Example 5-7 indicates four types of texture motion:

1. Streaming designates a texture consisting of individually perceived layers.
2. Flocking is indicative of the collective movement of numerous micro sound objects. These small objects exhibit similar traits that allow the listener to group the sounds together.
3. Convolution applies to complex spectromorphologies that are described as twisting, coiling, entwining or interweaving. In this context, convolution does not refer to the digital signal processing technique.

section (measures)	spectral space t-stick 1 (upper graphic) / t-stick 2 (lower graphic)	behaviour	predominant texture motion	motion / growth
2 (102 - 118)		loose vertical co-ordination ——— moderately pressured horizontal passage	convolution	plane
4 (185 - 209)		loose vertical co-ordination ——— lightly pressured horizontal passage	streaming	plane
5 (210 - 240)		loose vertical co-ordination ——— pressured horizontal passage	convolution	pericentrality ——— divergence
6 (241 - 281)		moderate vertical co-ordination ——— highly pressured horizontal passage	flocking ——— steaming	ascent ——— undulation

Example 5-7. T-stick spectromorphological phenomena.

section (measures)	spectral space t-stick 1 (upper graphic) / t-stick 2 (lower graphic)	behaviour	predominant texture motion	motion / growth
10 (424 - 434)		tight vertical co-ordination — pressured horizontal passage	turbulence	agglomeration
11 (435 - 501)		tight vertical co-ordination — highly pressured horizontal passage	convolution	undulation — convergence
13 (505 - 540)		tight vertical co-ordination — pressured horizontal passage	convolution	pericentrality — divergence & convergence
13 (541 - 587)		loose vertical co-ordination — voluntary horizontal passage	turbulence — streaming	dissipation — convergence

Example 5-7. T-stick spectromorphological phenomena, continued.

4. Turbulence also applies to complex spectromorphologies and describes chaotic and irregular collaboration among sounds, although some concurrence is still perceived within the stormy unevenness.

The prevailing t-stick texture motion is convolution, which should not be surprising considering the digital instruments originate in the same instrumental family.[40] In other words, the t-sticks were conceived as a homogeneous group in *CAS*, thus their playing techniques and sounds were devised to intertwine effectively with each other. A similar scheme results in the interweaving of the four strings into one uniform sound; the 2 violins, viola and cello are often constrained to the same general register, especially in the first half of the piece.

The first half of section 13 (mm. 505-40) demonstrates convolution in the t-sticks. 'Fan', 'lasso' and 'airplane' playing techniques (review these techniques at **2.3.3. Playing techniques)** in both t-sticks create complementary sounds (i.e., pericentral motion and growth) from the DMIs. Their tight vertical co-ordination accentuates one composite undulating voice. Similar to the section 2 example of pressured horizontal passage above, the pericentrality motion and growth of section 13 gives way to voluntary horizontal passage (behaviour) and both turbulence and streaming (texture motion) at mm. 541, prepared for maximum pressure-release by one final elongated and exaggerated 'lasso' in both t-sticks. The effect on spectral space is dramatic and climactic because the slow 'lasso' technique induces a simultaneous spectral divergence and convergence. That is to say, the 'lasso' consists of precise instrument tilting and rotating that brings about two diverging pitch bends. Moreover, the upper pitch bend tends to dominate toward the end of the technique, creating a high frequency convergence.

Example 5-8. 'Fan', 'lasso' and 'airplane' techniques on t-stick 1 (mm. 507-40).

[40] Soprano, alto and tenor t-sticks exist. In addition, some models incorporate vibration actuators for programmable haptic feedback and send their data to a computer using either wired USB, or Bluetooth or ZigBee wireless protocols.

The separation of t-stick sounds in the second half of section 13 (mm. 541-87) is evidence of streaming. T-stick 1 exhibits turbulence while t-stick 2 reiterates clear percussive onsets. The distinctness and independence of each t-stick from one another in the final passage of *CAS* is indicative of a global intensification of materials, which was first described in relation to section 7 (**4.4.1. Section 7**).

5.5. Orchestral spectral space

The concept of spectral space also applies to the acoustic instruments of the ensemble. An evaluation of acoustic instrumental pitch and pitch deviation results in an understanding of orchestral spectral space, as well as behavioural, textural and directional growth patterns.[41]

I remind the reader of the wind instrument scordatura and the supposition that detuning the chamber orchestra brings the listener closer to a perception of real-world inharmonic sound as music (as discussed in Chapter 3, **3.3.3. The physicality of music**). Pitch deviation away from tempered tuning in the orchestra is seemingly intrinsic to orchestral spectral space in *CAS* and leads to a stronger acoustic and digital instrument integration. For example, the detuned upper winds, assisted by violin harmonics, create a highly convincing blend with the inharmonic t-stick timbre in section 4 (mm. 185-209), so much so that a t-stick 'illusion' is produced by the recapitulation of winds and strings in section 9 (mm. 380-423).

Acoustic instrumental behaviour (e.g., vertical and horizontal temporality) is concomitant with the DMIs. The most transparent interactions (e.g., tight vertical co-ordination) occur among the acoustic instruments and the keyboard in section 7 (mm. 282-362). For instance, choices in orchestration reinforce acoustic and digital instrument integration through convincing sound colour mixtures. Timbral blending, or lack of blending, plays a role in creating voluntary or pressured horizontal passage; the more

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[41] For an explanation of pitch (i.e., musical note), refer to **6.5. Orchestral pitch space**.

disruptive the blend, the more pressured the passage becomes. Notable blending especially occurs at the beginning of new segments (e.g., mm. 315 and 335), matching subtle timbral shifts in the keyboard.

In section 11 (mm. 435-501), both texture motion and directional motion and growth reinforce acoustic and digital instrument unity. The predominant spectromorphological features are convolution (as defined in **5.4.3. T-stick spectromorphological phenomena**) and undulating motion, which are achieved via *molto vibrato* indications for the wind instruments.

5.6. Summary

In this chapter I began with a look at the formative principles of electroacoustic spectral space in *CAS*. Next, I individually examined the MIDI keyboard, t-sticks and acoustic instruments in relation to the sounds they produce, focussing on spectromorphological parameters such as: behaviour, texture motion, and directional motion and growth.

6. Chapter 6 – Pitch space and harmony

6.1. Introduction

In Chapter 3, I looked at the musical implications of sound from our wide-open sound world (**3.3.2. The wide-open sound world**). In particular, we saw how our reception of 'sound as music' defined musical space and potentially conveyed a 'physicality' – as described in this document – of music. If sound is potentially perceived as music, then it is the composer's responsibility to organise sound and its constituent elements (e.g., pitch space) in a musically meaningful way. In this chapter, I consider sound as 'harmony' by first explaining the origins and formative principles of pitch space and harmony in *Catching Air and the Superman.* Second, a description of keyboard, t-stick and orchestral pitch spaces follows. Third, I present examples that illustrate motion and growth pitch patterns in the composition.

6.2. Formative principles

6.2.1. Spectral and partial tracking analyses

The first and most consequential approach to creating a pitch space for *CAS* entailed the spectral and partial tracking analyses of musical material freely composed for the DMIs. This early compositional stage was also moderately restricted by mappings used throughout the composition. For example, the slow unfolding of the keyboard part – a seemingly infrequent chord at first – beginning at mm. 2 was a result of mapping sinusoid zero-crossings to rhythm.[42] The following steps outline the procedure of deriving pitch space and harmony from the sound of the DMIs.

1. I freely created musical materials for all of the digital instruments – nothing for the acoustic instruments of the ensemble. At this stage, compositional structure had been nearly established, thus the duration of material and the sorts of musical gestures required were already known.

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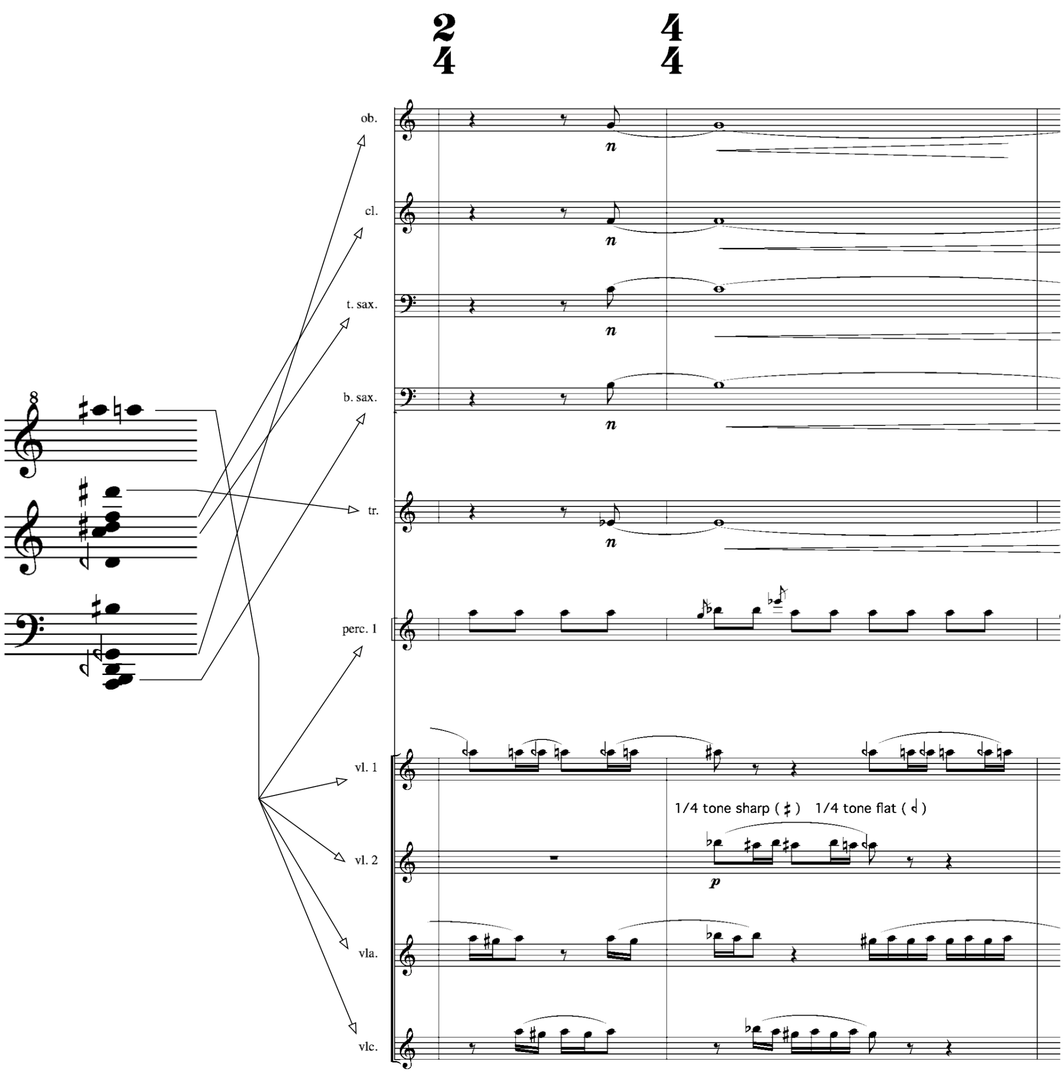
[42] I first discuss mappings in Chapter 3 (**3.4.3. Mapping objectives**). In addition, mapping sinusoid amplitude to pitch space is found in this chapter (**6.2.2. Amplitude mapping**) while a correspondence between sine wave zero-crossings and rhythm is treated in Chapter 8 (**8.2. Formative Principles**).

2. I performed and recorded the composed material myself.

3. I subjected the recorded results of both the MIDI keyboard and t-sticks' music to spectral and partial tracking analyses. Two computer applications, AudioSculpt and OpenMusic, were used in this procedure.[43]

4. The spectral data of the software output was transcribed. In the case of the keyboard, transcriptions took the form of notated chords, each spread over several staves encompassing the range of fundamental



Example 6-1. Spectral analysis transcription of first keyboard chord (mm. 2), orchestrated for winds, vibraphone and strings (mm. 5-6).

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[43] AudioSculpt is a sound analysis and processing tool, created by Niels Bogaards, Philippe Depalle and numerous contributors. OpenMusic is a visual programming language based on CommonLisp/CLOS, created by Carlos Agon, Gérard Assayag and numerous other contributors. Both applications are distributed by IRCAM.

frequencies producible by acoustic instruments (i.e., 27 to 4200 Hz). Alternatively, the t-stick data was transcribed as single notes. Frequency precision and output range were a result of several parameter adjustments in both AudioSculpt and OpenMusic. For instance, most chords contained quarter-tone indications, seeing how the microtonal approximation of the spectral analyses had been set to quantise to this amount.[44]

5. I treated the chordal transcriptions of the MIDI keyboard material as collections of moveable pitch classes, although the pitches of the minimum and maximum frequencies retained their vertical positions in relation to the remaining notes of the chord. The inner notes were freely moved around or even omitted. The 'composer's ear' always made the final judgement as to what notes of the transcriptions were relevant and how the notes were distributed in the music (see Example 6-1, above).

6. Transcriptions of single tones (i.e., from the material of the two t-sticks) were also treated as pitch classes. They served as fundamental pitch centres in the composition, especially in the second half of the piece.

6.2.2. Amplitude mapping

A second pervasive methodology for deriving pitch space has already been suggested above: vertical pitch space span mapped to sinusoid amplitude values. That is, sine wave amplitude values were taken as limits for constraining a vertical pitch space that encompassed the fundamental frequencies producible by acoustic instruments at maximum span. Furthermore, a large-scale divergence or convergence of pitch space was often created by mapping increasing or decreasing amplitudes to pitch span. On numerous occasions, amplitude-to-pitch mapping worked hand-in-hand with the aforementioned spectral and partial tracking analysis approach (**6.2.1**).

I made several preliminary decisions prior to each implementation of amplitude mapping:

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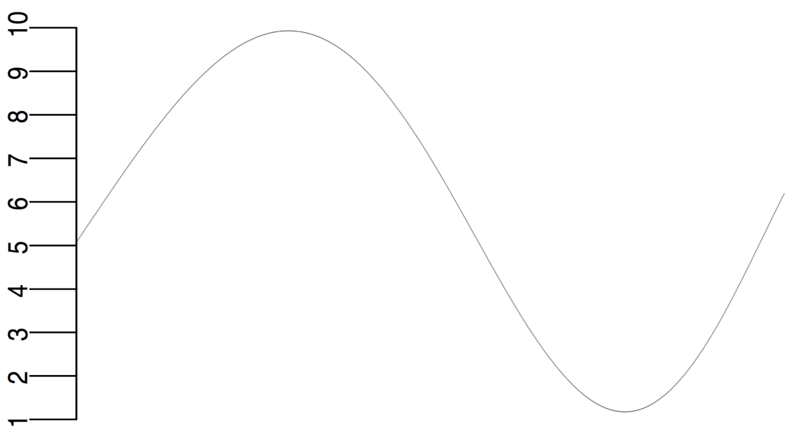
[44] This dissertation does not describe the exact implementation of AudioSculpt and OpenMusic. Examples of their usage in composing *Catching Air and the Superman* (i.e., transcribing sound into musical note information) would only illustrate a normative implementation, which is well-documented by other sources.

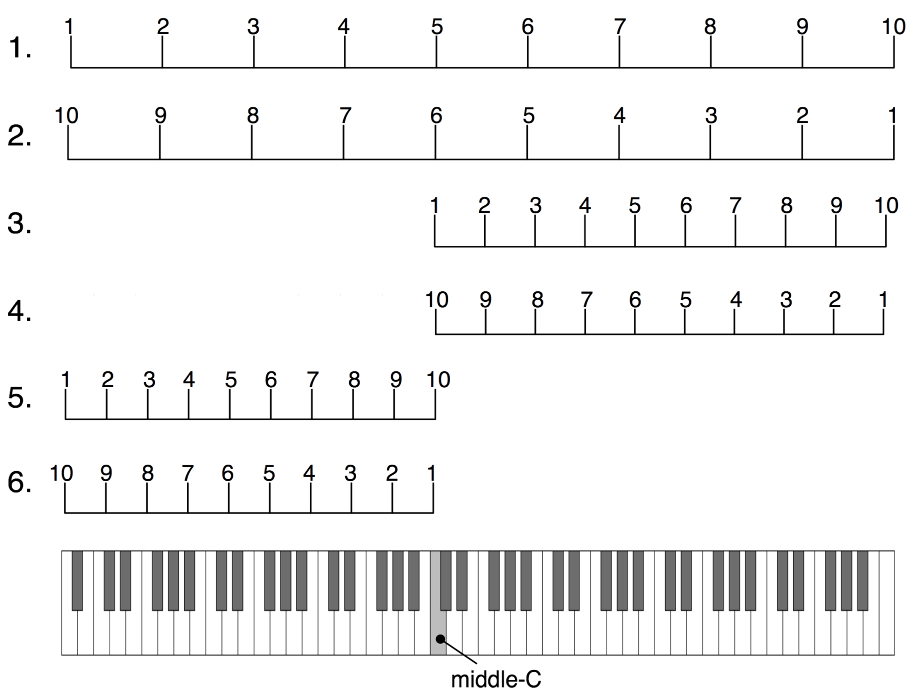
1. I chose between following either the exponentially increasing or decreasing sinusoid. The reader is reminded that a series of overlapping sinusoids – every sinusoid producing a separate continuum of amplitude and frequency values – provided structural information for each section of the composition (refer to Chapter 4, **4.3. Formative Principles**).

2. Sine wave amplitudes were scaled to fall within a decimal number range of 1.0 to 10.0 (Example 6-2).



Example 6-2. One cycle of a sine wave. Amplitude (*y-axis*) measured on a ten-unit ruler.

3. I mapped the amplitude values of the chosen sine wave to several different note ranges and orientations. As part of this procedure, a set of



Example 6-3. Six different orientation-rulers.

> rudimentary rulers (each measuring ten units) were made and literally laid across a piano keyboard in different orientations (see Example 6-3, above).

Mapping amplitude to pitch in this fashion contributed to a malleable and flexible methodology for establishing a general pitch space span. For example, determining the hyper-attenuated note range of the opening material for strings and vibraphone (beginning at mm. 3) entailed applying the span of orientation-ruler 3 (refer to Example 6-3) to the process of selecting pitch material from the spectral analysis of the first keyboard chord (refer to Example 6-1, page 74). The selected sinusoid data for this point in the piece yielded an amplitude range of 4.9 to 5.0. When scaled to orientation-ruler 3 and then approximately mapped to a piano keyboard note range as described above, these values gave me a minor second: G-sharp to A-natural. The note A-natural was chosen as the central note because of its correspondence to the top note of the keyboard spectral analysis (transposed down one octave so that the vibraphone had the means to play the note). Moreover, the importance of A-natural as one of the more pronounced tones of the MIDI keyboard chord in the first half of section 1 (MM. 3-59) confirmed its role as the central string pitch.[45] Refer to my discussion on *Orchestral pitch space* (**6.5**) for further exemplification of amplitue-to-pitch mapping.

6.2.3. Music model

The third determinant of pitch space has already been discussed in Chapter 3 (**3.5.3. Motif and harmony model**). A short passage from Ravel's *Le Tombeau de Couperin* (Example 3-3, page 42) served as a model while composing the latter half of section 7, especially mm. 315-46. The influence of triadic harmony from this example spread to the rest of the central seventh section, thus imbuing this part of the composition with tonal overtones.

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[45] The audio recording accompanying my dissertation does not correctly portray this keyboard sonority. The keyboard chord was improperly played during the premiere performance, except for its first occurrence at mm. 2.

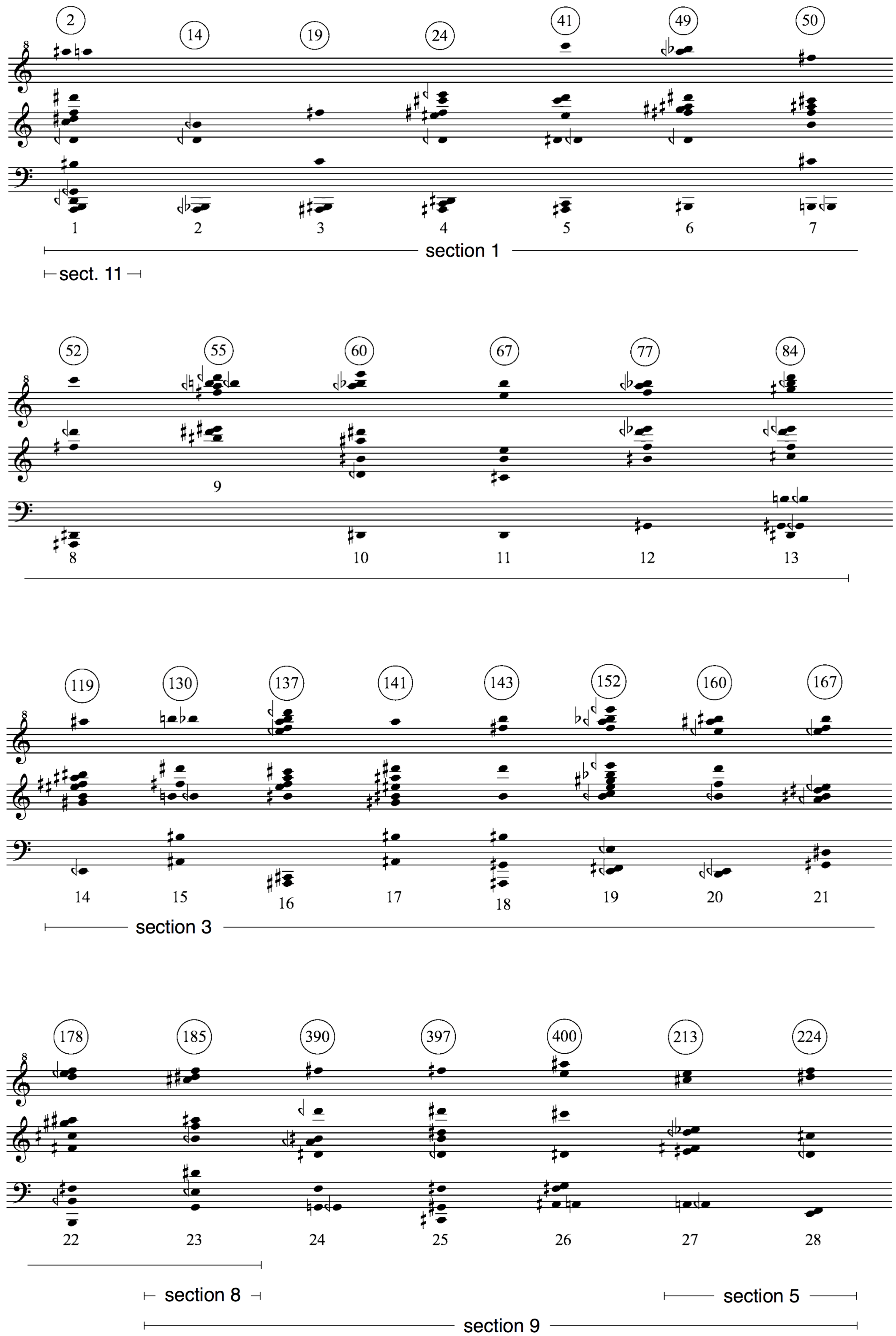
6.3. Keyboard pitch space

The goal of the following discussion is to spotlight the role of the keyboard as a generator of pitch material for the acoustic instruments of the ensemble. I explore t-stick and orchestral pitch spaces later on.

The keyboard is equally a source of harmonic and inharmonic sound throughout *CAS.* For me, its most important role is to provide a series of twenty-eight pitch collections or sonorities, even though its inharmonic sound colour is a significant contributor to eliciting perceptions of bouncing and breaking objects with all their representative acoustical properties (e.g., micro-impact onsets alluding to the physical substance of object and surface; continuous micro-variations of spectra suggesting a redistribution of energy on each bounce recurrence). Example 6-4, below, illustrates all of the twenty-eight sonorities and their locations within the composition.

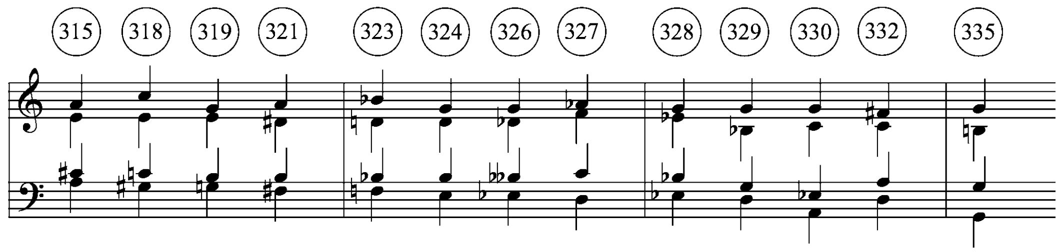
The keyboard material in sections 6, 7, 12, 13 and refrain are absent from Example 6-4. The timbre of the instrument in sections 6 (mm. 242-81), 12 (mm. 502-04) and 13 (mm. 505-39) is particularly inharmonic and predominantly percussive in behaviour. These parts are representative of the abstract electroacoustic attributes of the instrument and are discussed earlier, in Chapter 5 (**5.3. Keyboard spectral space**). The next paragraph deals with the keyboard pitch space in section 7.

The keyboard pitch space of section 7 (mm. 282-362) and the ending refrain, which is a transposition of mm. 295-98 up a perfect fourth, evoke, on the one hand, the narrow treatment of pitch space in the strings at the beginning of the composition, and on the other hand, the *Prélude* of Ravel's *Tombeau de Couperin.* A prolonging of a narrow pitch space characterises the beginning of each segment of section 7 (i.e., mm. 282, 298, 315, 335, 361) and is mostly represented in the right hand of the keyboard music by the reiterating 16th-note motif (this particular motif is identified in **7.3.1. 16th-note alternation**). The latter half of section 7, however, alludes to the triadic



Example 6-4. Twenty-eight pitch collections generated by spectral and partial tracking analyses of the keyboard chords. Measure numbers, in which each sonority first appears, are above the staves. Sonority number and the section in which each sonority is found, are indicated below the staves.

harmony of Ravel's *Prélude.* For example, the harmonic progression of the four-measure model (i.e., the *Prélude*) is reproduced twice: in mm. 315-35 (Example 6-5), sounding a major second lower than the original; in mm. 335-56, sounding a major third lower.[46]



Example 6-5. Harmonic progression in *Catching Air and the Superman*, extracted from the *Prélude* of *Tombeau de Couperin.* Measure numbers appear above the staff.

6.4. T-stick pitch space

The 'voices' of the t-sticks are primarily inharmonic even though one may distinguish pitch material resembling a single note or chord. Exact musical notes have some importance and impact,[47] but are rarely needed, in favour of spectrally dense or inharmonic percussive sound. In the case of t-stick 1, significant notes are the high A-quarter-tone-sharp (mm. 184) and high B-natural (mm. 585), the latter reinforcing the B-natural of the acoustic instruments in the final measures of the piece. A spectral analysis of material generated by t-stick 2 uncovered the importance of F-sharp, which is played by the instrument at mm. 184 and around mm. 435. Moreover, the F-sharp of t-stick 2 is part of the opening sonorities of sections 11 (mm. 435) and 13 (mm. 505) (**4.4.3. Outer sections**).

6.5. Orchestral pitch space

Orchestral pitch space refers to acoustic instrument pitch delineation and is obtained from the sonorities generated by the three DMIs while being constrained by sinusoid amplitude-to-pitch mapping. As a result, large-scale

[46] The reader is reminded that the MIDI keyboard sounds microtonally higher than written. Generally speaking, notes in the upper register of the keyboard are closer to tempered tuning than notes in the lower register.

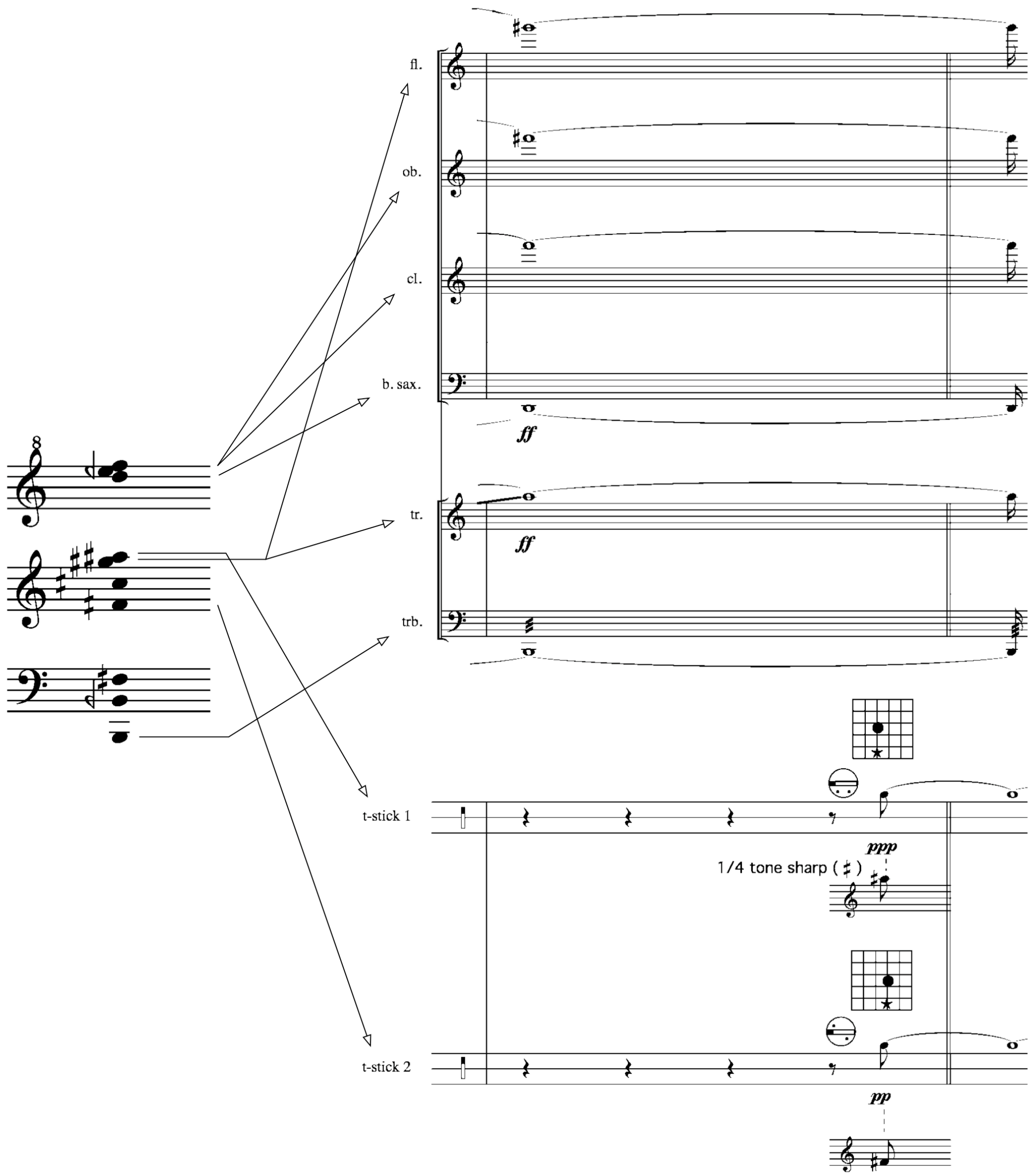
[47] And accurately playing them in tune requires extensive training on the t-stick.

pitch divergence and convergence are often created by mapping increasing and decreasing 'raw' amplitude data to pitch span (**Appendix A** contains an example of 'raw' data).

In the next few paragraphs, I first exemplify this approach to mapping in the first third of *CAS*. Next, I make reference to general motion and growth patterns applied to pitch space throughout the composition, including pitch divergence and convergence (**6.5.1. Directional motion and growth**).

In section 1 (mm. 1-102) of the composition, wind instrument pitch material at mm. 5 comes from the opening keyboard sonority at mm. 2. The vertical pitch distribution in the wind instruments is delimited by an amplitude reading of 4.9 to 5.0 at this point in the piece. The lowermost note in the baritone saxophone corresponds to a value of 5.0 on orientation-ruler 1 while the uppermost note in the oboe roughly corresponds to the same value on orientation-ruler 2 (orientation-rulers are on page 76, Example 6-3). Example 6-1, on page 74, illustrates the narrowly constrained orchestration of pitch classes drawn from the first keyboard sonority. From mm. 5 onward, large-scale pitch span divergence occurs by mapping decreasing amplitude values (scaled to orientation-ruler 1) to the lower voices of the winds and decreasing values (scaled to orientation-ruler 2) to the upper voices. Orientation-ruler 2 is the retrograde of orientation-ruler 1, thus scaling decreasing amplitude values to each of these rulers results in a sequence of notes that moves away from the centre of the piano keyboard (i.e., divergence).

Divergence in section 1 continues in the winds until the beginning of section 2 (mm. 103). Section 3 begins at mm. 119 and continues with the vertical expansion or dilation of pitch space – as if joined to the end of section 1. In this way, the dilation that begins in mm. 5 reaches a maximum width at the end of section 3, at mm. 184 (see Example 6-6, below). The pitch space at mm. 184 corresponds to sine wave amplitude readings of 2.6 and 7.4. Only



Example 6-6. Spectral analysis transcription of keyboard harmony (mm. 178), orchestrated for winds and t-sticks (mm. 184).

the lower value was used. Similarly to mm. 5, the lowermost note in the trombone corresponds to 2.6 on orientation-ruler 1 while the uppermost note in the flute corresponds to the same value on orientation-ruler 2. The tenor saxophone multiphonic has been omitted from Example 6-6; however, the instrument reinforces a perception of maximum dilation by accentuating a move to the upper end of its tessitura.

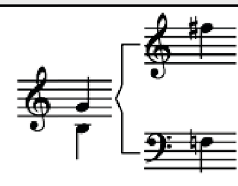
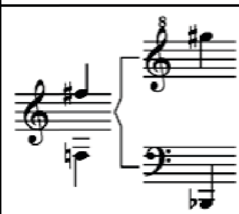
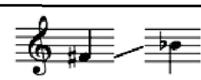
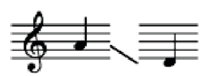
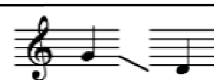
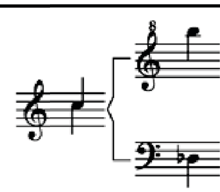
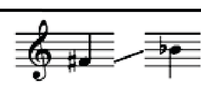
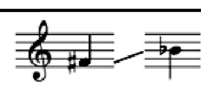
6.5.1. Directional motion and growth

Bi-directional (e.g., divergence and convergence) and uni-directional (e.g., plane, ascent and descent) motion and growth permeate through the entire composition and underscore the large-scale structure of *CAS.* Example 6-7 (pages 84-5) illustrates pitch space motion and growth patterns predominantly delineated by the acoustic instruments of the ensemble. The DMIs, on the other hand, are in control of transmitting motion and growth patterns in sections 5, 6, 10 and 12. Their sounds are best described as inhabiting a 'spectral' space, instead a pitch space (**5.4.3. T-stick spectromorphological phenomena**).

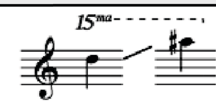
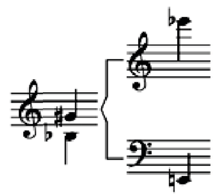
The measure number designations (second column) of Example 6-7 only delimit the parts of the composition in which the respective pitch space (fourth column) is found. They do not necessarily correspond to the complete section length. Furthermore, some sections possess more than one motion and growth pattern. For example, section 13 consists of several simultaneous layers that culminate in a musical climax around mm. 539. In this case, two layers ascend while three others diverge and converge concurrently. Consequently, a perception of divergence is achieved by a gradually widening of pitch space while motion and growth patterns resolve to a single dyad (i.e., E-natural and E-flat, outlining a major seventh) and impress a sense of convergence on the listener.

6.6. Summary

In chapter 6, I showed how spectral analyses of DMI sound yielded the tempered and quarter-tone pitch material on which I built a pitch space and harmony. Drawing from these analyses and observing the mapping objectives outlined in Chapter 3, I discussed methods of pitch organisation for the keyboard, t-sticks and acoustic instruments. The chapter concluded with a clarification of directional pitch motion and growth in the piece.

section	measures	motion / growth	pitch space	predominant instrument(s)
1	5 - 102	divergence		winds
2	103 - 118	plane		lower winds, t-stick 2, cello
3	119 - 184	divergence		winds
4	187 - 209	ascent		clarinet, oboe
5	210 - 241	divergence	inharmonic	digital instrument
6	242 - 281	ascent, undulation		
7	315 - 328	descent		cello, ten. saxophone
	334 - 347	descent		trombone, cello
8	363 - 379	divergence		strings
9	380 - 424	parabola		violins, piccolo
	391 - 420	ascent		clarinet, oboe
10	424 - 434	agglomeration	inharmonic	t-sticks
11	435 - 501	ascent		clarinet, trumpet, strings
12	502 - 504	divergence	inharmonic	keyboard

Example 6-7. Directional motion and growth.

section	measures	motion / growth	pitch space	predominant instrument(s)
13	523 - 538	ascent		piccolo
	505 - 539	divergence & convergence		winds
	534 - 539		inharmonic	DMIs
	526 - 539			strings
	570 - 584	ascent		winds, violins

Example 6-7. Directional motion and growth, continued.

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7. Chapter 7 – Object and motif

7.1. Definitions

The meeting point of object and motif requires explanation. Object and motif converge at the lower structural levels of *Catching Air and the Superman.* I define 'object' as a fixed entity almost always perceived as detached and in relief from its surroundings while 'motif' comprises a sequence of notes with its own consistent logic, in addition to an interconnectedness with previous and subsequent note sequences (i.e., other motifs). Phrase results from the joining of one motif to the next. An object may be subjected to simple external manipulation while a motif engenders organic growth and development. In *CAS*, a brief note sequence performed on a single instrument may exhibit characteristics that identify it as both object and motif – or one or the other – depending on the listener's perspective. The aleatoric bouncing gesture (Example 3-2 on page 37) exemplifies an ambiguous intersection of object and motif. It stands out from its surroundings due to its unique rhythmic contour (mm. 1-2, 543-69). At the same time, it is a vehicle for sustaining a sequence of interconnected notes or maintaining a melodic contour (mm. 91-102, 174-83, 387-420).

7.2. Two essential objects

I composed *CAS* with a conception of two objects in mind. One object, referred to as the 'chord-object' in this dissertation, consists of the vertical sonority best represented by the MIDI keyboard chord. The other object is essentially sustained or held (i.e., horizontal) sound rendered by the complex and continuous 'voices' of the t-sticks, and is referred to as the 'sustain-object'. Although numerous manifestations of the 'chord-object' and 'sustain-object' appear throughout the composition, held and sustained timbres become the most prominent object as the work reaches its conclusion. In this respect the listener may perceive an assimilation of the chord-object (i.e., 'the

Superman') by the sustain-object (i.e., 'Air') as crucial to a global understanding of the work.

The listener may identify an additional third object that implies both vertical and horizontal dimensions. It is made up of a quick reiteration of onsets that either sound like asymmetrical bouncing (e.g., mm. 234-58 [t-stick 2]; mm. 556-75 [t-stick 1]) or take the form of a controlled alternation between two 16th-notes (e.g., the initial material of the strings, beginning at mm. 3, or the predominate keyboard gesture from mm. 222-362). Although one might associate this succession of events with the existence of a third distinct object, its uniformity of timbre accentuates its horizontal character more than its vertical nature; it is related to an ornamental gesture such as a trill. Any asymmetrical bouncing sounds or alternating 16th-notes should, therefore, be associated with my second object, a sustained or held sound. The next few paragraphs deal with the chord-object. An explanation of the sustain-object follows afterward.

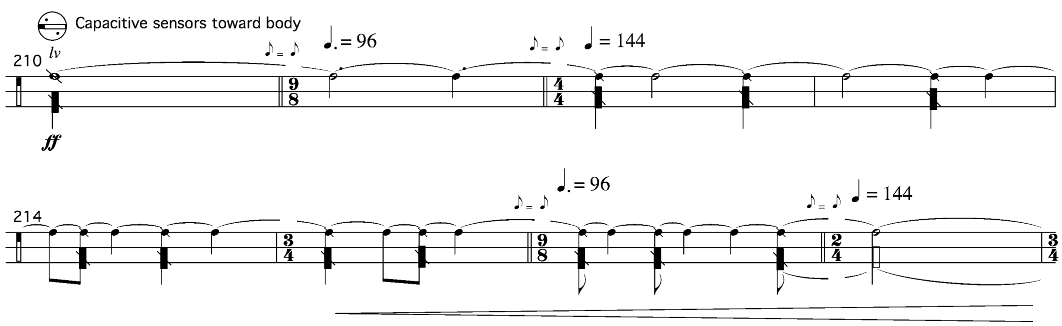
7.2.1. Chord-object (vertical)

In this section, I firstly identify the chord-object in the keyboard music. Secondly, I illustrate examples of the chord-object in other instruments.

A strongly articulated keyboard chord epitomises the chord-object, which is assigned the role of 'the Superman' (**3.2. Air and the Superman**). Its significance is most felt in the first part of the composition, whereas its presence is reduced during the second half. The keyboard chord decisively enters at mm. 2 and roots or anchors almost the entire first half of the piece through its spectral content and rhythmic presence. It is not an overbearing force, nor does it overwhelm or cover other musical material. Its repetition, with only subtle timbre changes, positions it in relief from its surroundings. The keyboard chord appears less frequently as a 'chord-object', distinct from its surroundings, in the second half of *CAS*. Instead, it plays a more co-operative role with other instruments. For example, in section 8 (mm.

363-79), it joins with the entire acoustic instrument ensemble in an effort to articulate a composite rhythmic pattern. In section 9 (mm. 380-423), the keyboard chords share a kinship with the vibraphone and marimba chords, and are gradually absorbed into the mallet instrumentalists' line. At mm. 494, the keyboard chord returns for one last appearance and leads to the forceful and climactic three-measure solo of section 12 (mm. 502-4), epitomising the ambiguous intersection between object and motif in *CAS* (the meeting point of object and motif was introduced in **7.1. Definitions**).

Other instruments owe their association with the chord-object to the omnipresence of the MIDI keyboard chord during the first half of *CAS.* For example, the 'one-off' bounce sounds of t-stick 2 in portions of sections 4, 5 and 6 (mm. 186-95, 210-34, 259-81) are clear examples of an another instrument producing sounds that recall the chord-objects firstly represented by the keyboard sonorities (Example 7-1).[48]



Example 7-1. T-stick 2 (mm. 210-17).

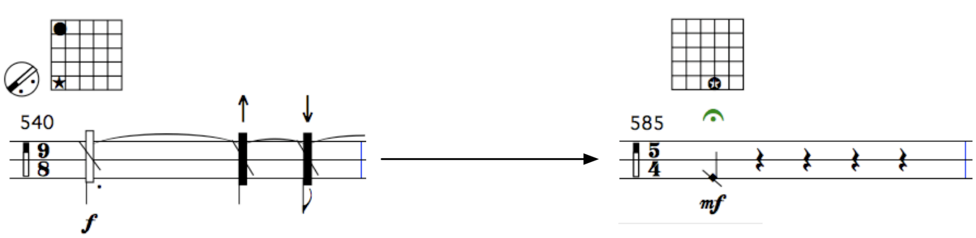
The next representations of the chord-object occur in the strings in section 7 (mm. 282-362). Beginning at mm. 314, the upper strings perform *pizzicato* triple-stops, followed by quadruple-stops at mm. 331. The violoncello contributes to the musical gesture with single-note and snap *pizzicati*. At the same time, the lower winds bark out *staccato* and accented chord-objects every few measures (mm. 316-45) that ultimately lead to section 8 (mm. 363-79). In turn, section 8 consists of an ensemble

[48] A slash through a t-stick note-head (i.e., a traditional note-head or thin vertical block) specifies a thrusting motion on the DMI and results in a 'one-off' bounce sound.

convergence upon the chord. That is to say, most instruments articulate a composite rhythm, producing a series of ensemble chords that represent a slow-to-fast bouncing pattern. As mentioned above, the *tutti* vertical sonorities of section 8 are less similar to chord-objects in that they are the result of co-ordinated rhythms in the entire ensemble. They envelop any surrounding material rather than remaining detached from their surroundings.

Beginning at mm. 441, the chord-object is suggested by the slap board in percussion 2. Percussion 1 comes in with the bass drum at mm. 473 and leads to several forceful and loud onsets in conjunction with the slap board, especially at mm. 485-501. The percussion instruments do not possess the timbral richness of the keyboard; however, their sharp articulations suffice enough to allude to the chord-object.

In the final segment of section 13 (mm. 540-87), t-stick 2 once again performs thrusting gestures that produce chord-objects while other instruments exhibit their greatest independence of the entire composition. A two-handed thrust on t-stick 2 is indicated in the score at first.[49] The t-stick passage ends with only a single finger and thrust (Example 7-2). The result is a low-frequency reduction, thus the sound is thinner and higher by the final note at mm. 588. The overall effect on the chord-object is an absorption of the object into the variegated ensemble texture.



Example 7-2. T-stick 2. mm. 540 is played with two hands, while mm. 585 requires a single finger.

[49] Two hands are indicated by a thin vertical block that crosses all three lines of the t-stick staff.

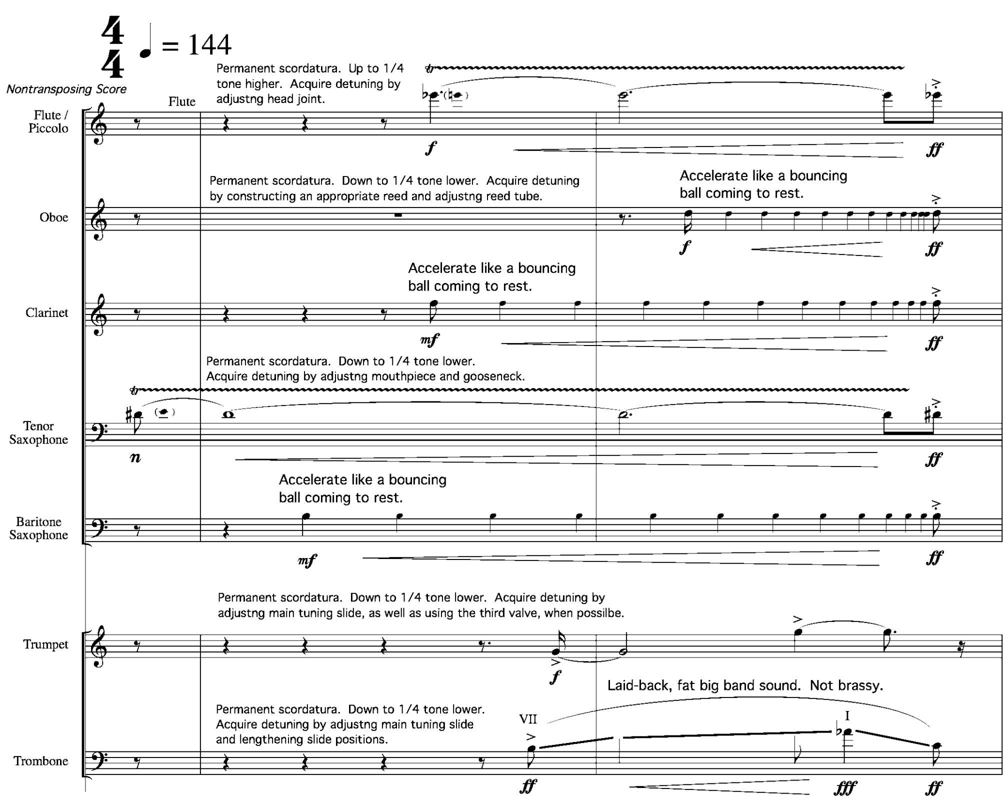
7.2.2. Sustain-object (horizontal)

In this section, I firstly identify the sustain-object in the music of the t-sticks. Secondly, I illustrate examples of the sustain-object in other instruments.

The sustain-object clearly comes to the fore in section 2 (mm. 103-18), represented by the t-sticks and violoncello with brief utterances from the wind instruments. The reader is reminded that the t-sticks metaphorically represent 'Air' (**3.2. Air and the Superman**). Section 2 constitutes a momentary pause – large-scale sustain – from the chord-objects in section 1. The same release from the chord-objects of section 3 occurs at the start of section 4 (mm. 185), when the continuous sound of both t-sticks enters in conjunction with violin 1. Moreover, a study of the score beginning at mm. 185 illustrates that t-stick 2 represents both the sustain-object and the chord-object (the resemblance of t-stick 2 'one-off' bounce sounds to the chord-object is described above **7.2.1. Chord-object**). In this way, a tension between sustain-object and chord-object manifests itself most transparently at the start of section 4 and continues through section 5 and into the first half of section 6 (mm. 185-258, in total).

A large section of the composition elapses before the sustain-object reappears in the t-sticks; in fact, the t-sticks are silent from mm. 284-422. A short eleven-measure t-stick duet begins with a pick-up in t-stick 1 at mm. 424. This entry is sudden and marked by a dramatic shift in ensemble texture and timbre. Similarly to the start of section 4, this passage (mm. 424-34) represents the tension between sustain-object and chord-object. In this instance, the continuous asymmetrical bouncing of t-stick 1 constitutes the sustain-object while t-stick 2 thrusts out repetitions of the chord-object. The interaction between sustain and chord terminates at mm. 435 when both instruments arrive at a convergence upon the sustain-object. For the remainder of the composition, the t-sticks predominantly represent the sustain-object, although they have numerous *forte-piano* dynamic indications that recall the articulative nature of the chord-object throughout sections 11 and 12 (mm. 435-501).

Other instruments in the ensemble, besides the t-sticks, are able to sustain a tone and, therefore, are capable of representing the sustain-object. For instance, the opening two measures (i.e., mm. 1-2) provide several manifestations of the sustain-object: the trill, the aleatoric bouncing gesture and held notes (Example 7-3). The remainder of section 1 and most of section 3 fortify a dialectic whose function is to examine the sustain-object in relation to the chord-object. While the chord-object is being assertively depicted by the MIDI keyboard (**7.2.1. Chord-object**), sustained sound is produced by the remainder of the ensemble. In particular, the winds literally hold tones throughout sections 1 and 3 or individually repeat a single tone (e.g., beginning around mm. 77). Furthermore, their overall pitch space is rigourously delimited through a process of divergence (**6.5. Orchestral pitch**



Example 7-3. Manifestations of the sustain-object in the winds (mm. 1-2).

space), beginning with a vertical range of a minor sixth (mm. 5) and arriving at an octave and a minor ninth by the end of section 1 (mm. 102), for example. It is the strictly controlled expansion of pitch space coupled with constrained musical gestures (i.e., sustained notes) that accentuate the nature of the winds as a single complex sustain-object.

In section 1 and the first half of section 3, the strings are unified by both a 16th-note musical motif (**7.3.1. 16th-note alternation**) and a constrained register. As stated above, I consider alternating 16th-notes as a manifestation of the sustain-object (**7.2. Two essential objects**). The sound of all four strings fuse together like a single-stringed resonating object, encompassing a minor second. The vibraphone is also sufficiently constrained such that its 8th-note repetition conveys a perception of sustained sound, especially because the vibraphone part initially asks for a semi-depressed pedal in section 1. As a result, the string and vibraphone, in addition to the winds, represent different manifestations of the sustain-object throughout sections 1 and 3, thus they counterbalance the chord-object produced by the MIDI keyboard.

Beginning in section 5 (mm. 222), the keyboard takes on a new role indicative of a sustained tone. The left hand performs a controlled alternation between two 16th-notes (i.e., a sustain-object). The same sustain-object, played by the keyboard and acoustic instruments, is an integral part of the central seventh section (mm. 282-362) of *CAS* (**4.4.1. Section 7**).

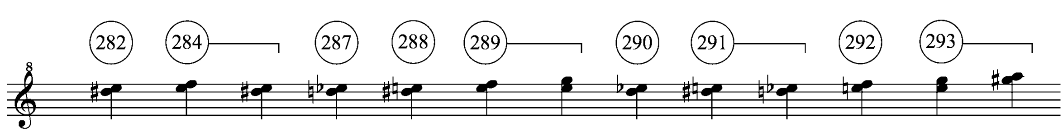
The sustain-object is noticeable throughout section 9, from mm. 380-423 (e.g., aleatoric bouncing in the mallet instruments) and section 10, from mm. 424-34 (e.g., resonating gestures of t-stick 1). The final three sections of the composition (mm. 435-587) and the four-measure refrain typify the sustain-object, which predominates the acoustic instrument writing, especially through pitch space motion and growth centred around F-sharp. Contrary to the opening three sections, the sustain-object takes precedence over momentary appearances and allusions to the chord-object. Moreover, the presence of the sustain-object in section 13 accentuates the climax of *CAS* at mm. 539 though a process of simultaneous divergence and convergence.[50]

7.3. Three essential motifs

In Chapter 4, I state that section 7 (mm. 282-362) functioned as a model for subdividing many of the other main sections of the work (**4.3. Formative principles**). In addition, section 7 transparently presents the three foundational motifs of *CAS.* The following discussion takes each of the motifs individually by firstly illustrating their use in section 7 and secondly, exemplifying how they are employed in the rest of the composition.

7.3.1. 16th-note alternation

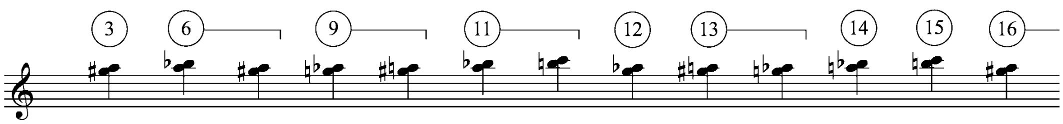
As previously stated, one characteristic of the sustain-object in *CAS* is alternating 16th-notes (**7.2. Two essential objects**). However, the progression of alternating 16ths from one note to the next also attributes a motivic character to the reiteration of 16th-notes, ultimately suggesting large-scale melody. Example 7-4 illustrates the melodic contour of the keyboard material at the beginning of section 7 (mm. 282-93). I show the melody as a dyad progression in order to account for all of the notes. We do not actually hear this passage as a progression of discrete two-note groupings, but rather we detect different streams that allow us to identify a melodic profile. This implementation of alternating 16ths occurs at the start of each segment of section 7 (mm. 282, 298, 315, 335, 361) and is doubled (beginning at mm. 298) by the acoustic instruments of the ensemble.



Example 7-4. A dyad progression containing the alternating 16th-note motifs at the beginning of section 7 (mm. 282-93).

[50] Related discussions on climax in *Catching Air and the Superman* are found at **6.5.1. Directional motion and growth** and **8.5.1. Divergence of pulse**.

Examples of the 16th-note alternation motif in the rest of the composition are as follows. Firstly, it appears in the strings beginning at mm. 3 and is doubled by the 8th-note line of the nickel vibraphone. Example 7-5 encapsulates the flow of motifs played by the strings at the start of section 1 (mm. 3-17), illustrating large-scale melody and an equivalence to the opening keyboard material of section 7 (Example 7-4). Furthermore, the 16th-note motif occurs at the start of each segment (mm. 3, 60) in a similar fashion to section 7. Following the first appearance of the t-sticks in section 2 (mm. 103-18), the 16th-note alternation motif returns in the strings at the start of section 3 (mm. 119-29). This is the last occurrence of the motif, played by the strings, in the first half of *CAS*.



Example 7-5. A dyad progression containing the 16th-note motifs, played by the strings, in unit 1/segment 1 of section 1 (mm. 3-17).

The use of the 16th-note alternation motif in the first half of the composition is not restricted to the strings. The clarinet and saxophones perform the motif, prepared by an aleatoric bouncing gesture, at the end of section 1 (mm. 96-102). Furthermore, a version of the motif consisting of augmented note values (i.e., 8th-note alternation) occurs in almost all of the winds at one point or the other in the latter half of section 3 (mm. 149-72).

Changing the note values of the alternating note motif occasionally occurs in the second half of *CAS*. Flute, oboe and clarinet trills in section 11 (mm. 435-501) represent the motif with diminished values, recalling the introductory two measures (mm. 1-2). Beginning at mm. 494, alternating notes in the left hand of the keyboard gradually become an augmented version of the motif, first in 8th-notes (mm. 497-501) and then in quarter notes (mm. 505-32). The motif only occasionally takes on its original appearance of alternating 16ths in the form of brief flourishes in the winds, especially in section 13 beginning at mm. 509. In these instances, the strict symmetrical note alternation appears varied; an incomplete neighbour figure replaces neighbour tone motion.

7.3.2. Scales

In the keyboard music of section 7, 16th-note alternation motifs (**7.3.1 16th-note alternation**) naturally flow into scale motifs (mm. 293-94, 309-10, 346-47). Scale motifs refer to both an ascending and descending melody almost entirely consisting of chromatic motion. In section 7, they are short-lived, operating on the lower levels of musical structure and encompassing a single measure before giving way to the divergence and convergence motif (**7.3.3. Divergence/convergence**). As a result, they act as transitions between alternating notes and the divergence/convergence motif. Their transitional nature is accentuated by a change in texture, as in mm. 310 and 347 where acoustic instrument support suddenly drops away at the introduction of the scale motif. In the latter case, the clarinet, violin 1 and viola linger on, functioning as a type of resonance from the music preceding mm. 347.

Section 1 parallels section 7 in its use of the scale motif. In the case of section 1, however, the scale motif affects a perception of both the lower and higher structural levels of *CAS*. Instead of being contained within one measure, as in section 7, the scale motif is treated heterophonically in the strings throughout segment 1/unit 2 of section 1 (mm. 18-40) and is escorted by a large-scale descent in the vibraphone (see Example 7-6, below). The motif exists as small cells in the strings, sometimes only two notes and seemingly linked to an alternating note motif; however, a close study of any of the string lines uncovers the globally descending motion, especially when compared to mm. 3-17. Example 7-6 illustrates the vibraphone's large-scale melodic motion, which reinforces the descending scale motif in the strings.

Example 7-6. Reduction of vibraphone music (mm. 18-41).

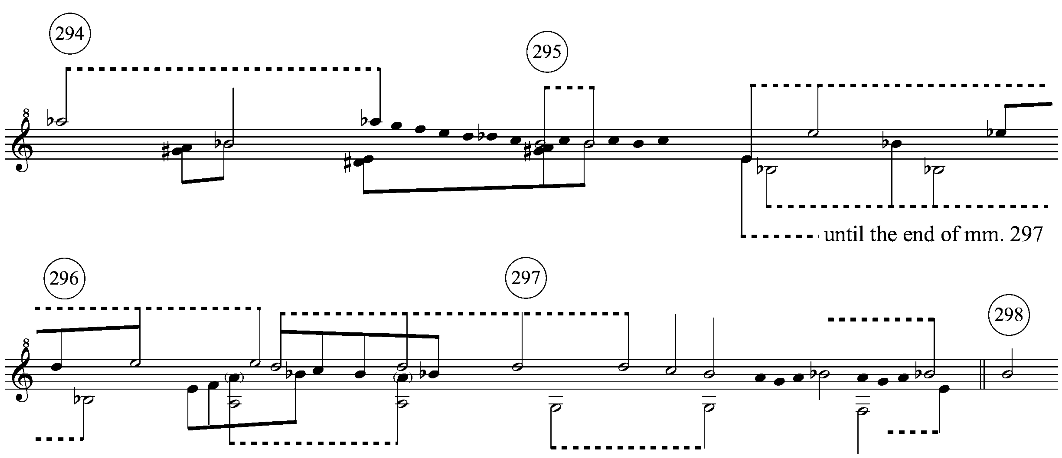
Earlier in this chapter, I indicated that the aleatoric bouncing gesture as described in Chapter 3 (**3.4.1. Bouncing**) exemplifies an ambiguous intersection of object and motif (**7.1. Definitions**). Moreover, in Chapter 3, I suggested that a gradual domination of higher frequencies over lower frequencies is often maintained in bouncing gestures. Both of these attributes of the aleatoric bouncing gesture contribute to the identity of the gesture as a scale motif throughout *CAS*. For instance, early occurrences of aleatoric bouncing in the work happen in the oboe (mm. 91) and trumpet (mm. 94); the first occurrence is in mm. 1-2. At the same time as the oboe or trumpet freely accelerate, emulating a bouncing object coming to rest, they use physical playing techniques and/or mechanical means to raise the frequency of their tones. The result approximates a rising microtonal scale, thus this musical gesture demonstrates a microtonal form of the scale motif. Furthermore, the interconnectedness between oboe and trumpet brings about large-scale melodic motion, which ultimately conjoins the flute, oboe and trumpet, and leads to the textural build-up that concludes section 1 (mm. 92-102). A similar technique at the end of section 3 (mm. 168-83) combines trumpet, clarinet and oboe.

One final example of the scale motif exists in the first half of the composition. In section 4 (mm. 185-209), the clarinet (mm. 187) and oboe (mm. 204) collaborate on creating stepwise ascending motion. The composite line is based on the scale motif with augmented note duration values.

In the latter half of *CAS*, the scale motif takes the form of the rising aleatoric bouncing gesture and large-scale melodic ascent or descent. Firstly, the mallet instruments perform the rising bouncing gesture in section 9 (mm. 410-20). In addition, excellent examples of bouncing immediately follow the climax of the composition in section 13 (mm. 543-61), where rising aleatoric bouncing gestures permeate the winds and contribute to each instrument's independence. Secondly, a large-scale melodic ascent or descent appears on numerous occasions.[51]

7.3.3. Divergence/convergence

In section 7, motivic flow forms a phrase structure culminating in an intersection of descending and ascending contours. That is to say, the movement from the '16th-note alternation motif' (**7.3.1. 16th-note alternation**) to the 'scale motive' (**7.3.2. Scales**) concludes with what I call the 'divergence/convergence motif'. Example 7-7 details the descending and ascending voice-leading of the first segment of section 7 (mm. 294-97). The first measure (mm. 294) contains alternating descending and ascending scale



Example 7-7. Reduction of keyboard music (mm. 294-97).

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[51] Refer to the table of Example 6-7 (Directional motion and growth) on pages 84-5 for measure and instrument designations.

motifs. The actual divergence/convergence motif encompasses the third beat of mm. 295 up to and including mm. 297 and converges upon B-flat. In addition, the left hand diverges downward a perfect fourth beginning on B-flat in mm. 295, arriving on F-natural in mm. 297. The B-natural at the end of Example 7-7 corresponds to the first note of the 16th-note alternation motif of segment 2, which begins at mm. 298. As with all previous motifs (i.e., 16th-note alternation and scale motives) the divergence/convergence motif recurs in subsequent segments of section 7 (mm. 311-14, 327-34, 357-60).

In addition to the structural influence of the divergence/convergence motif on section 7, the motif has a vital effect on the large-scale structure of the surrounding sections. My earlier discussions on *Keyboard spectral space* (**5.3**), *T-stick spectromorphological phenomena* (**5.4.3**) and *Orchestral pitch space* (**6.5**) highlight the importance of structural divergence and convergence.

7.4. Summary

With this chapter I drew distinctions between object and motif. Concerning object, I described the 'chord-object' as being more present in the first half of *CAS*, and diminished, assimilated or even absorbed by the 'sustain-object' during the second half of the composition. In addition, in this chapter I examined three essential motifs at the lower structural levels of the piece by illustrating their implementations in section 7 and then elsewhere in *CAS*. Their small-scale motivic activity was shown to have large-scale implications.

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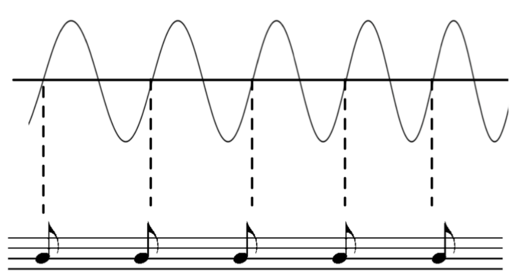
8. Chapter 8 – Rhythm, timing and tempo

8.1. Introduction

In this chapter, I discuss rhythm as an agent on behalf of timing and tempo. Timing refers to the placement of musical materials along the horizontal timeline of the composition. And with regard to tempo, the musical score rigidly stipulates a reading of 144 quarter-notes *per* minute or its equivalent of 96 dotted quarter-notes in compound time throughout *Catching Air and the Superman*, with the exception of two *ritardandi* and two *accelerandi* in the first half of the piece. Despite the general tempo regularity, a 'composed' pulse, intrinsic to the presentation and pacing of material, often undermines a perception of the music being played at an even speed. Following a discussion on the formative principles of rhythm and the feature identification of rhythmic grids, I exemplify how grid sequences and freely treated rhythm are organised at different moments in the composition.

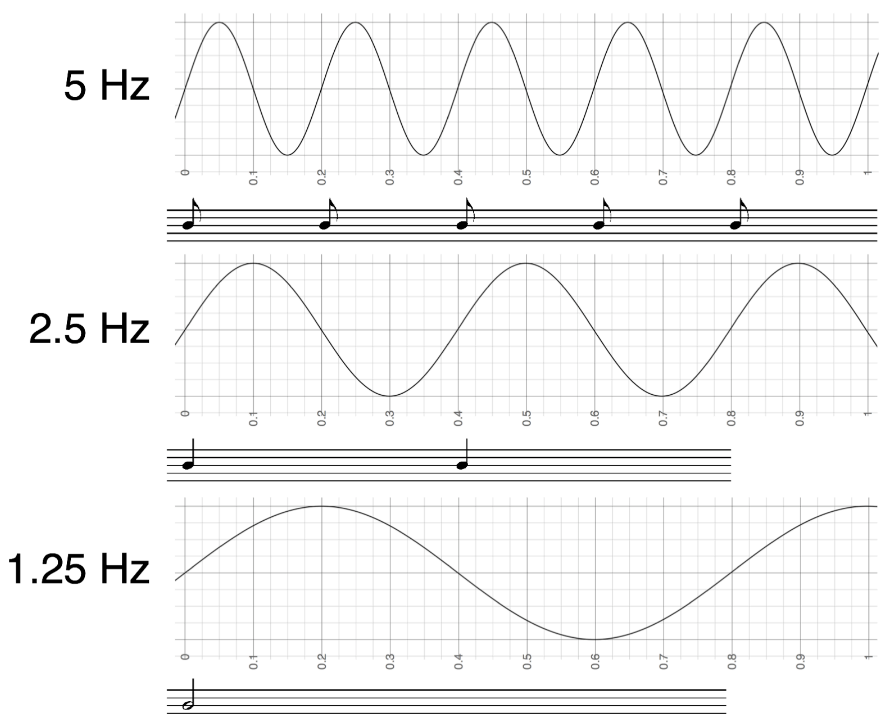
8.2. Formative principles

The reader will recall a mapping objective from Chapter 3: zero-crossings of an exponentially decaying sinusoid are mapped to onset times (**3.4.3. Mapping objectives**). More precisely, a new note occurs at the start of each cycle (i.e., at every zero-crossing and where sinusoid phase equals 0º [Example 8-1]). Next, in Chapter 4, I described how reducing the number of wavelengths of overlapping sinusoids led to the creation of thirteen sections in *CAS.* Moreover, I stated that each of the thirteen sections was embedded



Example 8-1. Zero-crossings, at 0º phase, mapped to note onset.

with entire or partial replicas of the initial overlapping sinusoids, scaled to fit section duration and possessing a frequency range of 0.004 to 5.0 Hz (see **4.3 Formative principles)**. From the upper limit of this frequency threshold I calculated the foundational note length – two hundred milliseconds – upon which rhythm, as an agent of timing, would be measured. If one cycle equals one note (Example 8-1), the fastest frequency (i.e., 5.0 Hz) allows for five notes *per* second or one note every two hundred milliseconds. If I assign an 8th-note beat to the value of one note, five 8th-notes every second can be expressed as a Maelzel Metronome reading of 300 8ths *per* minute or 150 quarter notes *per* minute. I lowered the tempo of MM. = 150, arriving at 144 beats *per* minute as the base tempo in *CAS*[52]. Frequencies less than 5.0 Hz yield longer musical note values as a consequence of having one cycle equal one note (Example 8-2). With the foundational note length and tempo



Example 8-2. Three sinusoids at different frequencies, each producing different note values.

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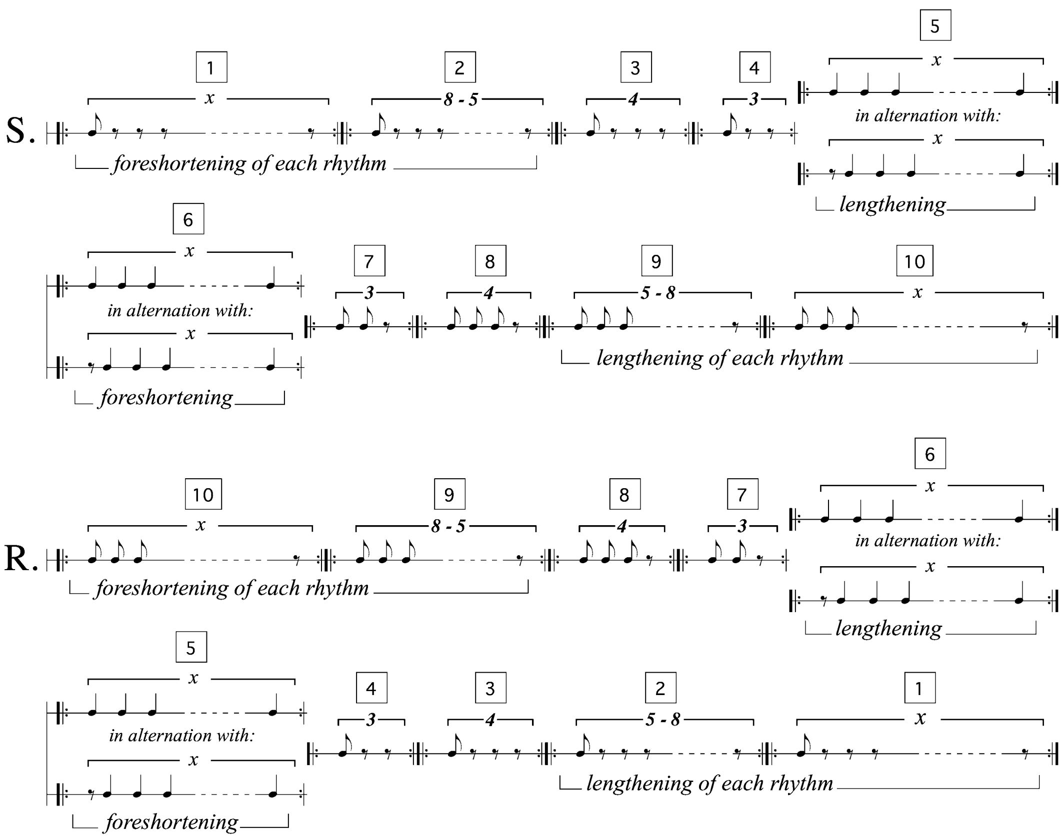
[52] In Chapter 4, I also make a footnote about the correlation between the value of 5.0 Hz and the *Presto* tempo of the *Finale* of Bartók's *Concerto for Orchestra*.

established, I set out to extract rhythmic features from zero-crossings to event onset mappings by following these steps:

1. I extracted the wavelength start times from the two overlapping sine waves, quantising to a value of two hundred milliseconds.[53] The two sinusoids provided two separate streams of values.
2. The timing measurements, expressed in 8th-note units at a tempo of MM. = 150 (i.e., 150 quarter notes *per* minute), were examined for discernible patterns and groupings.
3. I identified what I call 'rhythmic grids' from recurrent 8th-note patterns and arranged them into two sequences. Example 8-3 illustrates the initial grid set (based on the frequency-increasing sinusoid), entitled sequence *S*, and its retrograde (based on the frequency-decreasing sinusoid), entitled sequence *R*.[54]



Example 8-3. Two sequences, each consisting of ten rhythmic grids.
Sequence *S* (*set*) is followed by sequence *R* (its *retrograde*).

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[53] A simple computational procedure was implemented in Max/MSP.

[54] I introduced the usage of two sine waves, one the retrograde of the other, in Chapter 4 (**4.3. Formative principles**).

8.3. Overview of grids and sequences

From example 8-3, it is apparent that sequence duration is variable. The length of a sequence depends upon two factors: the number of times each grid is repeated and the number of events in grids 1, 5, 6 and 10. Concerning the second circumstance, grids 1, 5, 6 and 10 have a variable duration based on the number of events contained within each grid. For instance, the duration of the starting and ending patterns (i.e., first and tenth grids) is represented by an x - tuplet, meaning that it consists of a variable (x) number of 8th-notes. In the case of the first grid of sequence *S*, one onset (e.g, one note or chord) precedes a variable number of rests. In sequence *R*, the first grid (i.e., grid 10) consists of a varying number of onsets (e.g., a series of notes or chords) terminating in a single 8th-note rest. In both sequences *S* and *R*, the first grid begins as a long pattern. It is then gradually foreshortened. The opposite effect on grid length occurs at the end of each sequence (i.e., a lengthening of grids). Generally speaking, the effect of foreshortening at the start is swifter in sequence *S* than it is in *R* and the lengthening effect at the end is swifter in sequence *R* than in *S*. The variability of sequence and grid lengths is a natural result of having the duration of each sequence, and therefore the duration of each grid within a sequence, match the length of the scaled sinusoid on which a sequence is based.[55]

All but one of the thirteen sections and refrain of *CAS* contain at least one whole or partial sequence from Example 8-3. Out of these sections, most include both sequences *S* and *R* (see Example 8-4, below). In addition, most sections have an extracted or free rhythmic component (see **8.6. Extracted grids and free rhythm**). Section 12, a brief three-measure keyboard solo, contains a freely composed – and performed – *accelerando* and does not involve either of the sequences from Example 8-3.

[55] The scaling of sine waves was first mentioned in relation to the formative principles of Structure and form (**4.3**).

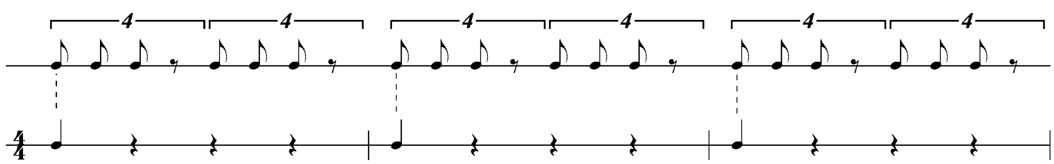
section number	measures	sequence *S* rhythmic grids	sequence *R* rhythmic grids	extracted/free rhythm
1	1 - 102	keyboard	winds	strings, percussion
2	103 - 118	t-stick 1	t-stick 2, cello, winds	
3	119 - 184	keyboard	winds	strings, percussion
4	185 - 209	t-stick 2	t-stick 1	strings, winds
5	210 - 241	t-stick 2	t-stick 1	keyboard
6	242 - 281		t-stick 1, keyboard right hand	t-stick 2
7	282 - 340	keyboard left hand	keyboard right hand	
	341 - 362	keyboard right hand	keyboard left hand	
8	363 - 379	keyboard, lower winds, strings		upper winds
9	380 - 423	keyboard	percussion	strings, winds
10	424 - 434		t-sticks 1 and 2	
11	435 - 501	t-stick 1, percussion	t-stick 2, strings	winds, keyboard
12	502 - 504			keyboard
13	505 - 540	winds, strings, percussion 1	t-sticks 1 and 2, percussion 2	
	541 - 563	t-stick 1	t-stick 2	winds, strings
	564 - 575	t-stick 2	t-stick 1, winds	winds, percussion
	576 - 587		t-sticks 1 and 2, winds, strings	percussion
refrain	588 - 591	keyboard left hand	keyboard right hand	

Example 8-4. Instrumentation of rhythm sequences *S* and *R*, as well as extracted/free rhythm for each section.

The two sequences, and the grids contained within each sequence, chiefly function as a system for selecting the points at which events happen (i.e., the timing of events) in relation to both other surrounding events and the passage of time in the piece. In numerous instances, the timing of musical material often suggests two clearly perceivable and distinct streams of activity, one stream composed of rhythms from sequence *S* and the other from sequence *R*. The most transparent examples occur during passages of strongly articulated onsets in section 5 and 6 (mm. 210-81), section 8 (mm. 363-79) and section 9 (mm. 380-423). Double timing streams provoke a perception of flexible or gradually fluctuating tempo throughout *CAS* with the exception of section 7, where the relatively consistent keyboard pulse stabilises the tempo. It is these simultaneous activity streams that result in a 'composed' pulse and especially 'composed' *accelerandi*/*ritardandi*, as well as affecting a sense of shifting tempo (**8.5. Accelerando and ritardando effects**). The next three sections more precisely detail characteristic applications of the rhythmic grids.

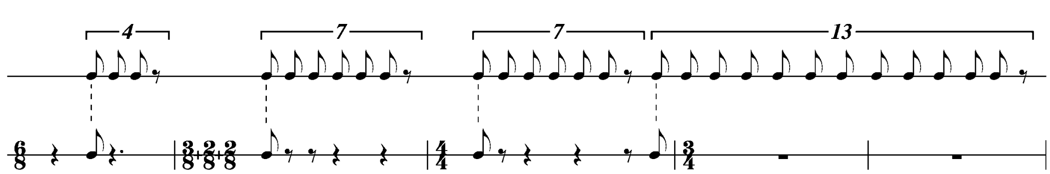
8.4. Groupings

Rhythmic grids are grouped together by two means. One form of grouping entails joining together more than one grid and articulating the entire collection with a single onset (Example 8-5). The keyboard chord, represented by the lower line of Example 8-5, takes up this role in section 3 (mm. 143-45). In this case, the grouping together of instances of grid 8 (sequence *S*) momentarily stabilises the tempo after a lengthy *ritardando* (mm. 127-42). That is, the perceived tempo at mm. 143 approximately matches the concluding pulse of the *ritardando*.



Example 8-5. Repetitions of rhythmic grid 8 of sequence ***S*** (top line) transcribed (bottom line).

The second form of grouping pertains to the articulation of groups of notes by a single onset, which is the starting event of a multi-note grid; grids 5 to 10 of sequence *S* are examples comprising multiple notes. Example 8-6



Example 8-6. A partial sequence of rhythmic grids 8, 9 (twice) and 10 of sequence *S* (top line) transcribed (bottom line).

displays this approach through a passage at the end of section 8 (mm. 375-79). The keyboard, low winds and strings, represented by the lower line of Example 8-6, articulate the starting note of each grid. The importance of the trumpet in this section of the piece should be apparent to the reader. Its rhythm, when combined with the strongly articulated onsets, reproduces the grids in their entirety, except for a couple of missing 8th-note rests.

In both Examples 8-5 and 8-6, groupings signal the arrival of a significant event in the large-scale structure. In the former case, the beginning of Example 8-5 (i.e., mm. 143) corresponds to the start of the second segment of section 3. A dramatic textural break precedes mm. 143. A single flute tone interrupts the texture of earlier measures, albeit very briefly. As a result of the textural pause, a change in string material (beginning at mm. 143) and the commencement of grid groupings, the second segment of section 3 (mm. 143-84) can be seen as a culmination of textural relations up to this point in the piece. In the case of Example 8-6, which corresponds to mm. 375-79, the punctuating of larger and larger 8th-note groupings (i.e., longer and longer grids) brings about a sense of culmination that requires a release of tension into contrasting material: a sustained harmonic in the violin (mm. 380), synchronised chords in the vibraphone and marimba (mm. 382) and the presence of more silence (i.e., notated rests) than in the previous measures. This change in texture coincides with the beginning of section 9.

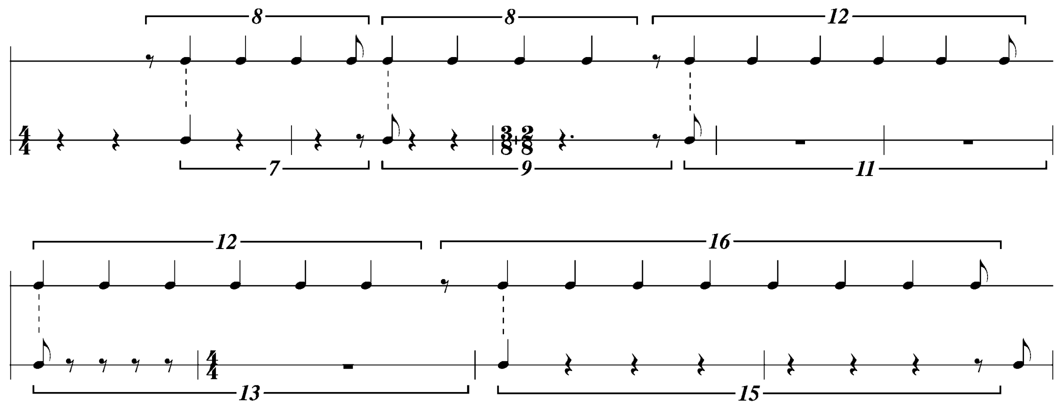
8.5. Accelerando and ritardando effects

Both sequences *S* and *R* (Example 8-3, page 103) exhibit inherent accelerating and decelerating attributes as a result of the foreshortening and lengthening of rhythmic grids. Foreshortening and lengthening are simple additive and subtractive processes that produce ‘composed’ (i.e., written out) *accelerandi* and *ritardandi*. A survey of the musical score reveals their numerous occurrences (see Example 8-7, below).

measures	accelerando	ritardando
2 - 59	keyboard	
84 - 102		keyboard
102 - 111	t-sticks 1 and 2	
186 - 191	t-stick 2	
210 - 226	t-sticks 1 and 2	
242 - 257		keyboard right hand
259 - 281		keyboard, t-sticks 1 and 2
283 - 309	keyboard left hand	
363 - 373	tutti (without t-sticks and percussion)	
374 - 380		tutti (without t-sticks and percussion)
380 - 424		keyboard
424 - 434		t-sticks 1 and 2
435 - 472	t-sticks 1 and 2	
441 - 473		percussion 2
473 - 501		percussion 1 and 2
506 - 536	winds	
507 - 532	t-sticks 1 and 2	

Example 8-7. Instrumentation of 'composed' *accelerandi* and *ritardandi* in *Catching Air and the Superman*.

Instances of *accelerandi* and *ritardandi* almost always demarcate the large-scale structure in *CAS*. For instance, the composed *ritardando* depicted by the keyboard chords of mm. 84-102 manifests its large-scale presence by firstly extending the 'conducted' *ritardando* of mm. 77-82 and then leading to the termination of section 1 through a gradual suspension of pulse. Example 8-8, below, corresponds to the keyboard music of the final measures of the *ritardando* (mm. 94-102) and illustrates both the lengthening of grid 5



Example 8-8. Lengthening of rhythmic grid 5 of sequence *S* (top line) transcribed (bottom line). The tuplet indications below the bottom line clarify the presence of a 'composed' *ritardando*.

(sequence *S*) and the articulation of the first events of multi-note grids (discussed in **8.4. Groupings**).

8.5.1. Divergence of pulse

Simultaneous accelerating and decelerating effects contribute to the most important moments of *CAS*, creating apices of rhythmic tension. Tempo variations caused by *accelerandi* or *ritardandi* could be described as deviations from, or back to, the central tempo of the composition. Such variations represent a divergence/convergence on the level of pulse and complement the use of divergence/convergence in the domains of spectral space (**5.4.3. T-stick spectromorphological phenomena**) and pitch (**6.5.1. Directional motion and growth**), as well as motif (**7.3.3 Divergence/ convergence**). For instance, the decelerating keyboard chord that accentuates the closure of section 1 (mentioned in relation to Example 8-8) occurs with simultaneous accelerating patterns in the winds and violoncello (mm. 96-102).

The climax of *CAS* (mm. 539) provides another keenly felt example of concurrent acceleration and deceleration in the ensemble, especially in the six measures (mm. 533-38) prior to the climax. First, the motivic timing in the winds defines the culmination of an *accelerando* that begins near the start of section 13 at mm. 506. Second, freely composed *accelerandi* – not originating in the foreshortening of rhythmic grids – in the keyboard, violins and viola begin around mm. 534 and reach their peaks at mm. 539. Third, the t-sticks produce an illusion of *ritardando* contrary to the *accelerandi* in the winds, keyboard and strings. That is to say, both t-sticks perform an elongated and exaggerated 'lasso' (mm. 533-39) that is both visually and aurally perceived as a slow motion imitation of the previous twenty-six measures (mm. 507-32).[56] Although the t-sticks do not decelerate from mm. 533-39 *per se*, their sudden change of tempo in relation to the rest of the ensemble, and in relation to their own previous material, creates a perception of slowly unfolding time or the perception of a protracted instance.

8.6. Extracted grids and free rhythm

The fifth column of Example 8-4, on page 105, specifies instruments that exhibit features of extracted and free rhythm in *CAS*. 'Extracted' refers to the drawing out or selecting of a single grid from either sequence *S* or *R*. The selected grid is freely used, perhaps adjoined to other extracted grids irrespective of where it falls within the sequence; the actual sequence is not evoked. 'Free' rhythm makes reference to freely composed rhythmic material.

8.6.1. Extracted grids

The strings predominately play extracted rhythmic grids in sections 1 (mm. 3-82) and 3 (mm. 119-38). They perform rhythms consistent with grid 9 (sequence *R*). In other words, they have 16th-note groupings spanning the duration of five, six, seven or eight 8th-notes. Slurs reinforce this organisation. Furthermore, shorter grids such as 8 and 7 (sequence *R*) are interspersed between longer grids. The suggestion here is that of a foreshortening of grid 9, leading to grids 8 and 7. This is consistent with sequence *R*; however, at this moment the whole of sequence *R* does not play a role in the strings. The foreshortening of grids corresponds to articulations in the large-scale structure of the piece. For example, shorter grids in all of the

[56] The reader should recall my description of 'lasso' technique from Chapter 2. 'Lasso' is a physical playing gesture that visually extend the arms, via the t-stick, and mimics the movement of twirling a lasso or lariat.

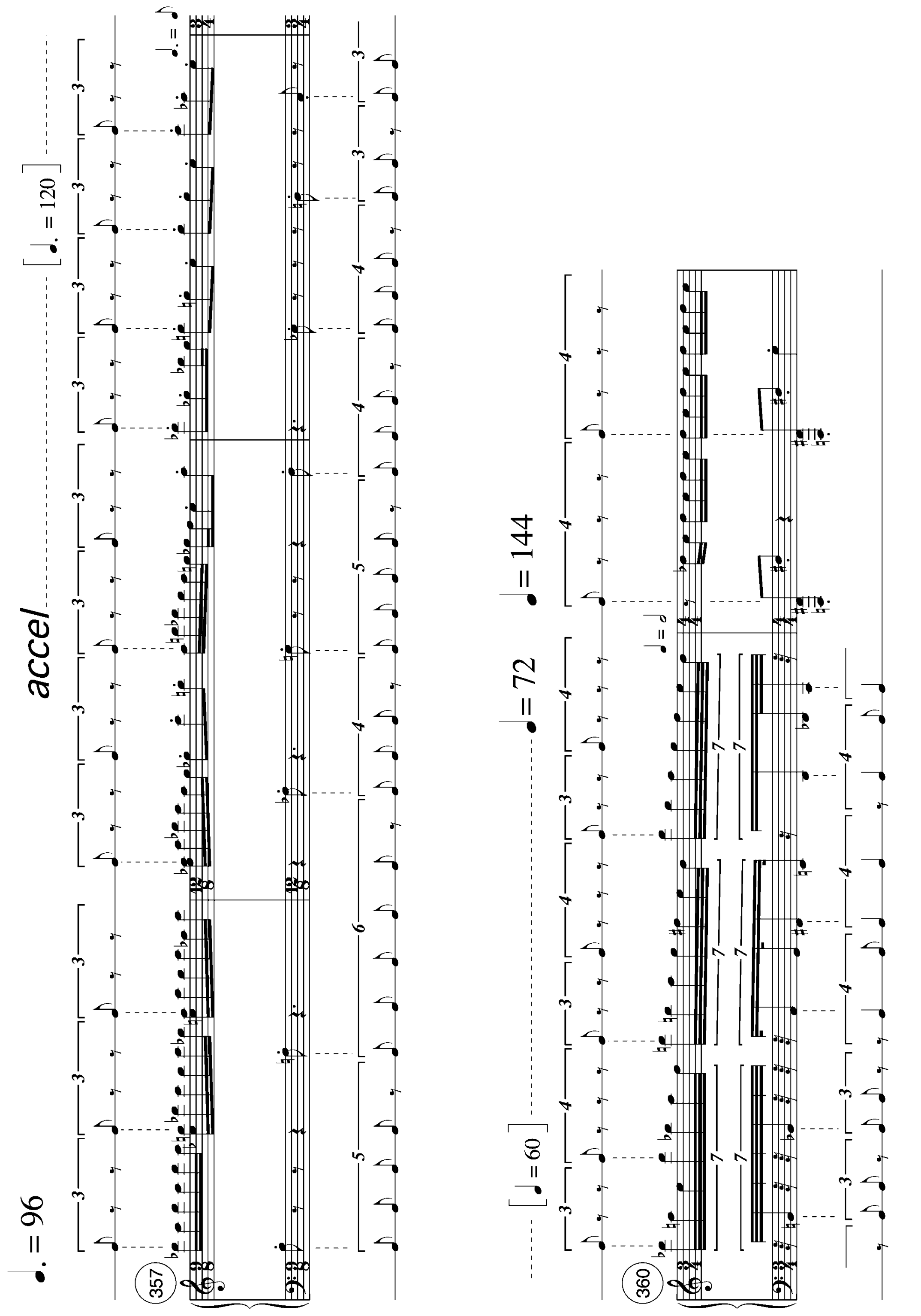
strings immediately precede the beginning of segment 2, section 1 (mm. 60) and segment 2, section 3 (mm. 143).

Extracted grids also assist in articulating changes in compositional structure near the end of section 7 by reinforcing a sense of acceleration into the final brief segment 5 (mm. 357-61). The overall acceleration is enhanced by supplementary grids that derive from the descending motion of the left hand. They are shown in the bottom line of Example 8-9 (on page 112) and, generally speaking, describe a foreshortening from grid 9 to 7 (sequence *R*). These extracted grids momentarily appear, whereas the grids shown on the top line of Example 8-9 are central to the entire seventh section. In this instance, the top line consists of grids 4 and 3 from sequence *R*, which plays a role in determining the timing of motifs in the right hand melody throughout section 7.

8.6.2. Free rhythm

The aleatoric bouncing gesture (see Example 3-2, page 37) epitomises free rhythm in *CAS* not only because of the freedom of interpretation it grants the musicians, but also because of its commonality with the rhythmic grid sequences. Both the bouncing gesture and sequences *S* and *R* share acceleration as an inherent property. The two introductory measures of the composition demonstrate acceleration as a result of bouncing gestures played by the oboe, clarinet and baritone saxophone (see Example 7-3, page 92).

Filling in rhythmic grids, or groups of grids, by one or more freely placed notes acts as another form of free rhythm. Sections 6 and 8 share this feature. During the second half of section 6 (mm. 259-81) beginning on the third beat of mm. 260, three intermediate onsets are equally distributed between articulations of grid 1 (sequence *R*), whose first note is played on every other higher sounding keyboard event – coinciding with every other G-natural in the left hand of the keyboard. The opening of this passage, mm. 259 up to and including the first two beats of mm. 260, encompasses four

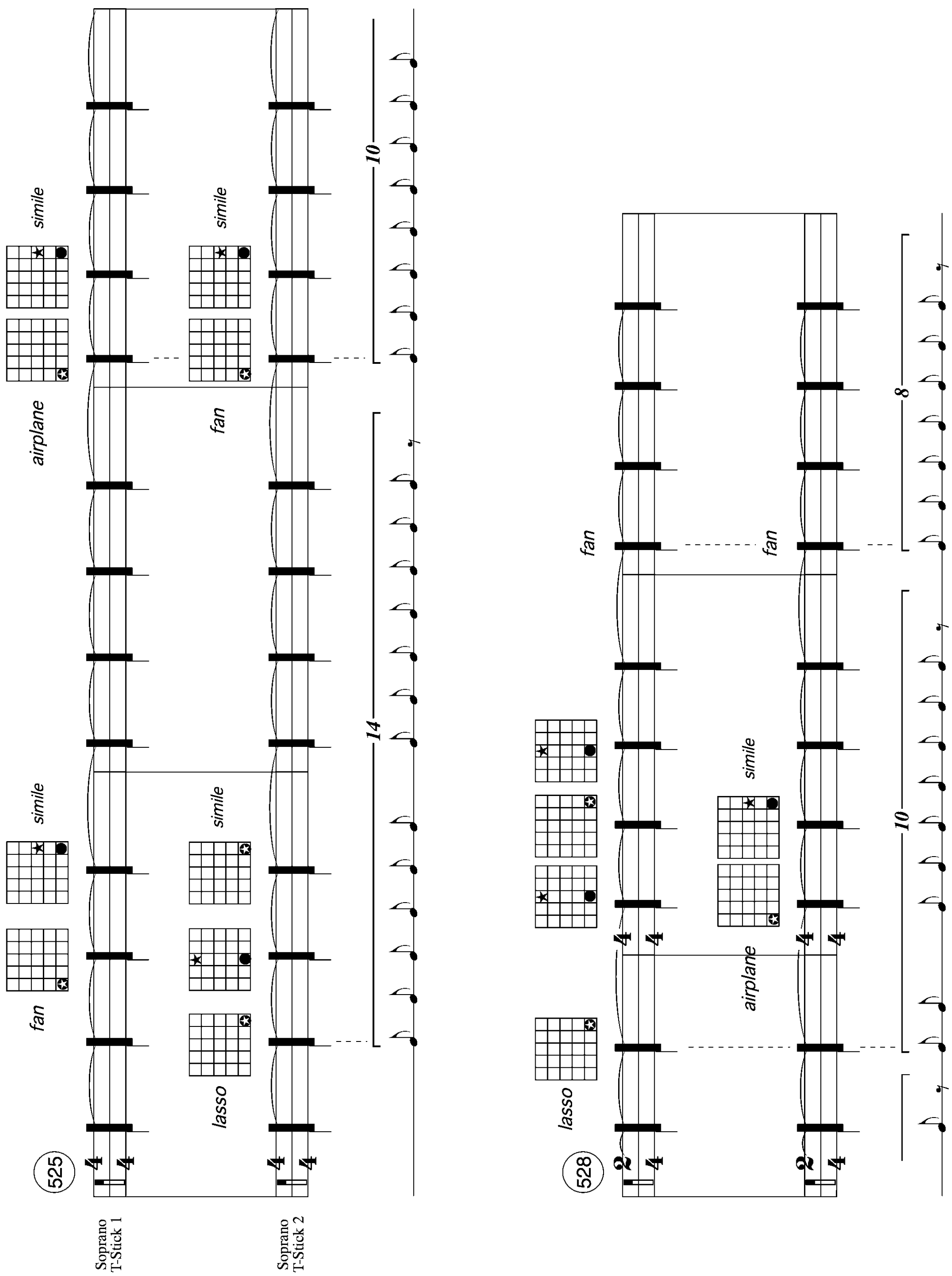


Example 8-9. Keyboard music (mm. 357-61) with grids 4 and 3 of sequence *R* (top line), and *extracted* grids 9, 8 and 7 of sequence *R* (bottom line). Tempo indications appear above each system.

intermediate onsets. In the case of section 8 (mm. 363-79), one single co-ordinated intermediate note in the upper wind instruments exists between grid articulations (sequence *S*) in the keyboard, lower winds and strings. The upper pitch boundary of the strings is also involved in sounding the co-ordinated intermediate note.

Evenly spaced intermediary events also occur in the first half of section 13 (mm. 505-32) and are performed by the t-sticks. Below, example 8-10 is an excerpt of this passage indicating the fluid physical gestures of t-sticks 1 and 2. The digital instruments strictly follow an intermediate quarter-note pulse while demarcating grid starting points by means of subtle variations in playing technique that produce equally understated modifications to t-stick timbre. A square grid above the staff line – a type of t-stick tablature – indicates changes in playing technique and timbre (this tablature system is described at **2.4. Notation**). The intermediate quarter-note pulse conveyed by the t-sticks continues until a variation in their playing technique occurs at mm. 533, which designates the final approach to the climax of the composition (**8.5.1. Divergence of pulse**). I make this observation in order to point out how extracted rhythm may coincide with or influence an articulation in compositional structure from time to time.

A third free rhythm form involves brief ornamental episodes. 16th-note flourishes cast as either alternating note or divergence/convergence motifs may reinforce the initial onsets of rhythmic grids. These flourishes are often loosely aligned vertically, being offset from any grid start point by an 8th-note. For example, all of the wind instruments have brief moments of free rhythm that increase rhythmic tension before the climax of the piece (mm. 509-36). The same figuration appears prominently in the winds immediately following the climax (mm. 543-60), as well as in the final measures prior to the refrain (mm. 578-84). In the latter example, grace note ornamentation in the violins parallel free rhythms in the winds. In section 13, free rhythm



Example 8-10. Music for soprano t-sticks 1 and 2 (mm. 525-30)
with grids 10 and 9 of sequence *R* (bottom line).

ornamentation contributes to a growing sense of independence exhibited by each instrument. It is this independence that distinctly characterises the conclusion of *CAS*, starkly contrasting the continuities of the opening sections of the work.

8.7. Summary

In this chapter, I identified what I call ‘rhythmic grids’, arranging them in two different sequences, one sequence being the retrograde of the other. I then described the movement and grouping of rhythmic grids. For instance, I showed how the sequential ordering of grids generated a flexible sense of tempo because sequences inherently include properties of acceleration and deceleration. The chapter concluded with examples of rhythms extracted or derived from grids, as well as explanations of freely treated rhythm in the composition. On numerous occasions I mentioned the importance of timing and tempo variations on large-scale structure due in part to the implementation of rhythmic grids.

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9. Chapter 9 – Conclusion

9.1. Document summaries

9.1.1. A technological trajectory in time

In the first two chapters of this dissertation I contextualised my use of digital technology in relation to the progressive application of electronic devices by composers from the twentieth century up to and including the first decade of this century. I placed digital musical instruments at the end of this chronological trajectory. In Chapter 2, in particular, I discussed the constituents of my own definition of a digital music instrument and exposed the essential t-stick features in relation to my definientia.

9.1.2. Concepts and models

In Chapter 3, I first dealt with words that are central to my title: 'Air' and 'the Superman'. Second, I presented an argument, which was based on an esthesic concern for the 'physicality' of music, for hearing sound as music. After that, I introduced bouncing and breaking sound scenarios as a fundamental concept in *Catching Air and the Superman*. In particular, the concept of bouncing was shown to have generated my interesting in mapping certain aspects of two overlapping sine waves to musical attributes. I also pointed to the foundational motion and growth processes of the piece (e.g., divergence and convergence) as they were observed in other composers' works. Moreover, I drew a connection between the motifs used in *CAS* and a short passage from the music of Maurice Ravel.

9.1.3. In the form of an arch (a one-off bounce)

I began Chapter 4 with a description of the structure and formative principles behind the creation of my piece. In particular, I illustrated how the proportioning of section duration roughly corresponds to the redistributed wavelengths of a sinusoid. Second, I analysed the structure of *CAS* by working from the middle, outward. I began with a structural analysis of section 7 (mm. 282-362), which was composed first and contains the structural ideas on which all other sections are organised. Following a look at section 7, I worked toward the outer parts of the piece, drawing out correspondences among them (e.g., proportioning of segments and units within each section; digital versus acoustic instrumental textures; consistency of inharmonicity) in an effort to uncover the arch-shaped form of the work.

9.1.4. Spectral and pitch spaces

I began with the formative principles of spectral and pitch space in Chapters 5 and 6, respectively. In both chapters, I pointed to the importance of DMI sound in establishing the fundamental spectral and pitch spaces as a result of my own approach to developing the 'voices' (i.e., sound synthesis) of the keyboard and t-sticks. The remainder of Chapter 5 contains a discussion on the spectromorphological phenomena primarily represented by the digital instruments, beginning with the keyboard and then the t-sticks. I showed how the DMIs successfully convey divergence and convergence motions, among others. I also provided graphical representations of t-stick spectral space in addition to audio samples of DMI sounds extracted and isolated from the composition. A similar analytical approach was taken in Chapter 6, beginning with the pitch space of the keyboard and then the t-sticks. I uncovered the twenty-eight sonorities derived from analyses of the MIDI keyboard sound. I also described the procedure of vertically constraining musical note range *via* amplitude mapping (based on sinusoid amplitude values). I concluded Chapter 6 with a detailed description of the pitch divergence and convergence, among other motion and growth processes, of orchestral pitch space.

9.1.5. Object and motif

Chapter 7 contains details concerning the use of objects and motifs in *CAS*. Instead of beginning this chapter with formative principles, as I did in previous parts of this document, I started by distinguishing between objects the motifs. After that, two objects, the 'chord-object' and 'sustain-object', were identified and exemplified. Finally, I described the three essential motifs of the piece. In both cases (i.e., objects and motifs) I mentioned their influences on large-scale structure.

9.1.6. Rhythmic grids

In Chapter 8, I focused on a rhythmic analysis of my composition and the effect of rhythm on tempo and the timing of musical material. First, I returned to my mapping objectives introduced in Chapter 3 (e.g., mapping sine wave period structure to musical note onset occurrences), aiming at explaining the formative principles of rhythm. Second, I introduced the term 'grid' as a way of conceiving the horizontal placement of musical material over the time span of the composition (i.e., timings). Third, the two key grid sequences of the piece were exposed. Fourth, a discussion on the organisation of grids and sequences was given, leading to examples of 'composed' *accelerandi* and *ritardandi* effects in the music. The chapter concludes with examples of how rhythm and rhythmic grids are treated more freely in *CAS*.

9.2. Contributions

I have endeavoured to formulate a methodology for applying digital musical instrument technology to compositional craft and especially amalgamating an expertise in traditional acoustic instrument compositional practises with an innovative approach to writing electronic music. The following three theories/methods, in particular, bring to light the outcome of my work. They constitute the principal original contributions of this thesis.

9.2.1. Beginning with the electronics

The materials for *CAS* were primarily created through an interaction with the digital instruments. That is to say, the initial musical material for the project was synthesised by computer while playing the DMIs. In this way, I took a reverse approach to developing the relationship between the electroacoustic and acoustic sound worlds of my piece. Mixed and live electronics composition typically use acoustic instrumental sound as a seed for the electroacoustic elements of the work (e.g., Davidovsky's *Synchronisms* series [1963-1977]). In *CAS*, the electronics come first. The earliest compositional stages produced complete musical segments for the MIDI keyboard and t-sticks. In turn, these segments informed the most essential ingredients of the composition, especially my pitch organisation and orchestration in the rest of the ensemble. In a related matter, if one composes for a DMI, one must research and experiment with the instrument beforehand, determining both idiomatic performance technique and sound – a skill that composers of acoustic instrumental music spend years developing thanks to a rich body of literature codifying playing technique and instrumental timbre. I am suggesting that beginning a new piece for digital and acoustic instruments by writing the DMI music first is absolutely in-line with traditional compositional practises. Nevertheless, certain limits and constraints must be realised if a composer intends to integrate digital and acoustic elements while attempting to navigate through the immense sound possibilities introduced by DMI composition.

9.2.2. Introducing limits and constraints

My research into areas of performance technique for the soprano t-sticks and sound synthesis for all the digital instruments (i.e., keyboard and two t-sticks) led to my establishing limits and constraints, which in turn shaped aspects of the compositional project. For instance, the musicians' control over sound production with the t-sticks was limited so that a number of primary musical gestures could be easily communicated to the audience and the rest of the ensemble. These gestures controlled sound excitation or initiation, articulation and volume. In general, audiences find it simple to correlate, say, a physical jabbing motion on the t-stick to a percussive attack, whereas other correspondences remain nebulous (e.g., tilting and rotating the instrument, mapped to uninterrupted timbre modulation). Nonetheless, I limited and constrained the gamut of possible physical playing gestures so that the t-stick would have an equally identifiable stage presence as the acoustic instruments by virtue of its limited range of effective movements.[57] Next, I was able to create a hierarchy of tension based on the t-stick movement vocabulary and consequently, I employed specific playing techniques at critical moments in *CAS*. The most obvious examples are found in sections 6 (mm. 242-81) and 13 (mm. 505-40), in which one or both t-sticks use dramatic physical gestures that entail fanning, twirling and revolving the instrument.

Instituting and adhering to limits and constraints allowed for a greater emphasis to be placed on composing with DMIs rather than aimlessly researching and developing the multitude of interactions and sound possibilities inherent in digital instrument technology. In this respect, my introduction of limits and constraints into the compositional project conformed to similar approaches found in Western art music. Igor Stravinsky (1947) said, "The more art is controlled, limited, worked over, the more it is free." (p. 63).[58] Stravinsky suggests here that the implementation of limits and constraints allows a rigourous control over materials and maximises the clarity of musical objectives in composing a piece of music. An objective might be to convey a familiar sense of form while at the same time employing a new system – or a new mode – that distorts structural points in the form.[59] Another objective – evident in *CAS* – might be to exemplify how a DMI musician functions equally with acoustic instrumentalists in terms of stage presence and musical sound production by introducing both a restricted

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[57] Acoustic instruments come with their own inherent constraints that allow the audience to identify them. For instance, an instrument roughly held parallel to the floor, laterally across the body and jutting out to one side will most likely be recognised as a flute. Moreover, certain sounds will be anticipated by the audience upon their seeing the instrument move.

[58] This statement was made in his third Norton lecture, entitled *The Composition of Music*, out of a series of six lessons.

[59] Stravinsky's use of the octatonic mode within the framework of Classical sonata form, for example.

playing technique, as described above, and movement on stage, as well as basing the sound of the DMI on a single source sound and its closely resembling derivatives.[60] The functioning of digital and acoustic instrumentalists as equal participants in a musical composition is an important activity in integrating technology and the compositional project.

9.2.3. Integrating technology and compositional project

In *CAS*, technology and project interconnect in the sense described by Varèse in Chapter 1 (page 5). In 1939, he suggested that aspects of the project (e.g., pitch, timbre, rhythm, mode of presentation) could be advanced by the invention of new machinery; first the machines are invented and then musical ideas flourish. At the same time, technology and project in *CAS* are coupled in the sense described by William Buxton in the 1980s: "[If] gesture and idea are tied, and the device is the instrument for capturing the gesture, then the range of input devices could be as diverse as the range of musical ideas" (Appleton, 1984, p. 50). With these words, Buxton offered a seemingly opposite outlook to Varèse. He suggested that first we have musical idea and its related gesture – essentially the compositional project. Then, appropriate input devices (i.e., machinery) could be invented to convey the idea and gesture.

Placing the compositional project as the primary directive is fundamental to my ideas on integrating technology and the project. This does not mean that I first conceive of the project, then build the machinery to fit the project (à la Buxton). The technological aspects of my composition do not play a lesser role. Nor is the electronic technology vigourously subordinated to the project.[61] Instead, I maintain the compositional project as my primary concern while weaving technological elements into it. In particular, I look for ways in which the limitations of project and technology come into direct

[60] In Chapter 5 (**5.2.1. Sound Synthesis**), I illustrate an approach to sound synthesis that involves first creating a source sound, followed by variations on the source sound.

[61] A characteristic clash that has been well-illustrated in *Boulez and the "machine"* (Jameux, 1984).

conflict. In fact, it is the *confrontation* of limits and constraints imposed by technology, on the one hand, and the compositional project, on the other, that serves as the material for this musical composition and, at the same time, unites them both.

9.3. Future directions

The narrow range of DMI performance techniques and sound are both an asset and a liability in my composition. On the one hand, a limited DMI technique and sound are a benefit in that they broaden the audience's appreciation of the t-stick as a musical instrument (as described in **9.2.2. Introducing limits and constraints**). On the other hand, a limited technique and sound may prove to be obstacles of sorts to performing musicians unless the practises behind these techniques are engaging and made inherent to the interpretation of a musical work. Performing on a t-stick must grant musicians a limited repertoire of playing techniques that are intrinsically bonded to supple transformations in instrumental timbre. Learning how to master these techniques and their related control over sound then become an issue of establishing rules for t-stick performance practise. In other words, if the t-stick – or any other DMI – is to be recognised as a musical instrument in the future, a trajectory starting with acoustic instrumental performance practise must be extended to digital instrumental practise. In this way, both digital and acoustic instrumentalists will be able to engage with each other, allowing themselves to draw on the human-to-human interactions and actions expected in music-making.

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APPENDICES

A – Sample of sinusoid data

Sequence S — *Sequence R*

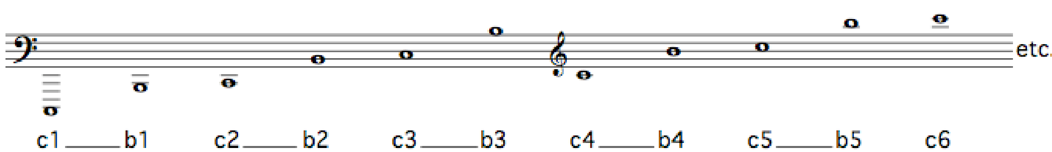
RUN	RUN		BEATS_0		AMP	AMP		BEATS_0		AMP	AMP
TIME	BEATS	bar	beat	eighth	PEAK	TRO	bar	beat	eighth	PEAK	TRO
		Sequence S					*Sequence R*				
16.32	4925	615	4	2	9.336	0.888	615	1	1	5	4.999
16.33	4930	616	4	1	8.874	1.221	615	1	2	5.001	4.998
16.34	4934	617	2	1	8.646	1.534	615	2	1	5.003	4.995
16.34	4937	617	4	1	8.407	1.688	615	3	1	5.006	4.992
16.35	4940	618	1	2	8.214	1.9	615	3	2	5.01	4.987
16.35	4942	618	2	2	8.033	2.172	615	3	2	5.015	4.981
16.36	4945	618	4	1	7.696	2.198	615	4	1	5.022	4.976
16.36	4947	619	1	1	7.695	2.401	616	1	1	5.026	4.967
16.37	4949	619	2	1	7.597	2.474	616	1	1	5.036	4.958
16.37	4951	619	3	1	7.471	2.595	616	1	2	5.046	4.958
16.37	4953	619	4	1	7.311	2.735	616	2	1	5.053	4.944
16.38	4955	620	1	1	7.196	2.928	616	2	2	5.068	4.942
16.38	4956	620	2	1	7.134	2.922	616	3	1	5.075	4.912
16.38	4958	620	3	1	7.004	3.016	616	3	2	5.093	4.947
16.39	4960	620	3	2	6.875	3.106	616	4	1	5.108	4.883
16.39	4961	620	4	2	6.847	3.228	616	4	2	5.124	4.886
16.39	4963	621	1	2	6.759	3.341	617	1	1	5.138	4.855
16.4	4964	621	2	1	6.687	3.428	617	2	1	5.08	4.842
16.4	4966	621	3	1	6.504	3.468	617	2	2	5.165	4.812
16.4	4967	621	3	2	6.524	3.505	617	3	1	5.198	4.809
16.41	4969	621	4	1	6.428	3.714	617	3	2	5.22	4.769
16.41	4970	622	1	1	6.244	3.68	617	4	1	5.224	4.744
16.41	4971	622	1	2	6.326	3.717	617	4	2	5.25	4.85
16.41	4973	622	2	2	6.09	3.783	618	1	1	5.282	4.702
16.42	4974	622	3	1	6.193	3.984	618	1	2	5.282	4.696
16.42	4975	622	3	2	6.116	3.905	618	2	1	5.272	4.649
16.42	4976	622	4	1	6.064	3.965	618	2	2	5.369	4.614
16.42	4978	623	1	1	5.897	4.042	618	3	1	5.39	4.623
16.43	4979	623	1	2	5.966	4.07	618	3	2	5.348	4.554
16.43	4980	623	2	1	5.88	4.115	618	4	1	5.467	4.521
16.43	4981	623	2	2	5.826	4.169	618	4	2	5.48	4.484
16.43	4983	623	3	2	5.632	4.518	619	1	1	5.457	4.477
16.44	4984	623	4	1	5.662	4.261	619	2	1	5.568	4.416
16.44	4985	623	4	2	5.655	4.299	619	2	2	5.595	4.394
16.44	4986	624	1	1	5.618	4.406	619	3	1	5.616	4.369
16.44	4987	624	1	2	5.637	4.386	619	3	2	5.692	4.286
16.44	4988	624	2	1	5.582	4.412	619	4	1	5.733	4.273
16.45	4989	624	3	1	5.565	4.464	619	4	2	5.516	4.205
16.45	4990	624	3	2	5.505	4.491	620	1	1	5.767	4.178
16.45	4992	624	4	1	5.481	4.56	620	2	1	5.867	4.103
16.45	4993	624	4	2	5.285	4.592	620	2	2	5.838	4.081
16.46	4994	625	1	1	5.353	4.59	620	3	1	5.974	4.004
16.46	4995	625	1	2	5.4	4.627	620	3	2	5.915	3.973
16.46	4996	625	2	1	5.367	4.667	620	4	1	6.06	4.212
16.46	4997	625	2	2	5.278	4.676	621	1	1	6.128	3.834
16.46	4998	625	3	1	5.31	4.695	621	1	2	6.143	3.791
16.47	4999	625	3	2	5.291	4.739	621	2	1	6.26	3.831
16.47	5000	625	4	1	5.213	4.757	621	3	1	6.326	3.637
16.47	5001	625	4	2	5.234	4.809	621	3	2	6.395	3.57
16.47	5002	626	1	1	5.183	4.798	621	4	1	6.403	3.671
16.48	5003	626	1	2	5.163	4.847	622	1	1	6.241	3.423
16.48	5004	626	2	2	5.099	4.911	622	1	2	6.608	3.359
16.48	5005	626	3	1	5.15	4.862	622	2	2	6.681	3.365
16.48	5006	626	3	2	5.14	4.869	622	3	1	6.778	3.202
16.48	5007	626	4	1	5.105	4.934	622	4	1	6.868	3.095
16.49	5008	626	4	2	5.102	4.926	622	4	2	6.889	3.032
16.49	5009	627	1	1	5.092	4.926	623	1	2	7.046	2.922
16.49	5010	627	1	2	5.077	4.927	623	2	2	7.018	2.802
16.49	5011	627	2	1	5.067	4.94	623	3	2	7.218	2.734
16.49	5012	627	2	2	5.043	4.949	623	4	1	7.343	2.574
16.5	5013	627	3	1	5.029	4.967	624	1	1	7.487	2.479
16.5	5014	627	3	2	5.037	4.972	624	2	1	7.569	2.341
16.5	5015	627	4	1	5.015	4.974	624	3	1	7.721	2.182
16.5	5016	627	4	2	5.018	4.986	624	4	2	7.844	2.083
16.5	5017	628	1	1	5.014	4.988	625	1	2	8.054	1.871
16.51	5018	628	1	2	5.009	4.992	625	3	1	8.246	1.673
16.51	5019	628	2	1	5.005	4.996	625	4	2	8.448	1.438
16.51	5020	628	2	2	5.003	4.998	626	2	1	8.614	1.18
16.51	5021	628	3	1	5.001	5	626	4	1	8.984	0.832

Example A-1. Section 2 (mm. 103-18) ‘raw’ sinusoid data from which timings (i.e., bar and beat columns) and amplitude-to-pitch values (i.e., AMP PEAK and AMP TRO columns) were extracted, generating rhythmic grids and ultimately the organisation of grids into sequences *S* and *R*. The AMP PEAK and AMP TRO values of Sequence *S* illustrate a convergence onto a value of 5.001. The opposite occurs for Sequence *R* values. Note that bar values do not correspond to musical score measure numbers.

B – Digital instrument specifications and performance notes

1. Keyboard

1. Use an 88-key (a0 to c8, see note nomenclature below) MIDI keyboard with two sustain pedals (half pedal effects are not required). Choose an instrument that implements realistic piano action (e.g., Yamaha P-140), including properly weighted keys that simulate graded hammer action (i.e., keys in the lower register have a heavier touch than those in the upper register).
2. Sound synthesis directly from the keyboard (i.e., onboard instrumental voices) is not required; however, the instrument must have MIDI output capability, either via USB or a standard MIDI output port.
3. The voice of the MIDI keyboard (i.e., sound synthesis) is generated by a Mac Pro, two 2.8 GHz Quad-Core Intel, running Max/MSP 5 and Apple's software LogicPro 8. Both the Max/MSP patch and Logic project are provided by the composer. See stage and technical set-ups for signal routing.
4. Depressing a key determines pitch and loudness in addition to the timbre of the instrument. Instrumental timbre can be 'frozen', or 'locked', by depressing the left and right foot pedals. When this occurs, the produced timbre is a result of the last keys touched, with pedals released. The left pedal corresponds to key range a0 to b3, the right corresponds to range c4 to c8. A key that locks the timbre is referred to as a pedal-lock note, which is indicated in the score (e.g., b3/a5), placed in a box next to the keyboard staff.

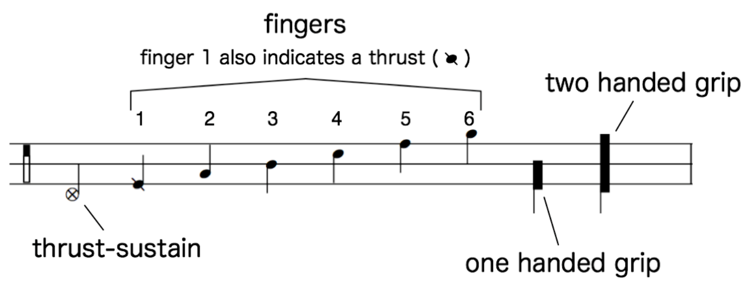


Example B-1. Note nomenclature as seen in the keyboard part.

5. The symbols for pedalling are: Rp = right pedal; Lp = left pedal. In addition, bracketed symbols appear in the keyboard part (not in the score) under the first measure of each page, and serve to remind the player of which pedal(s) are currently depressed. Observe all foot pedal indications with precision. Improper use of the foot pedal may dramatically alter the sound of the instrument.
6. The MIDI keyboard sounds microtonally higher than written. Generally speaking, notes in the upper register of the keyboard are closer to tempered tuning than notes in the lower register. In addition, lower notes tend toward inharmonicity (i.e., percussive quality).

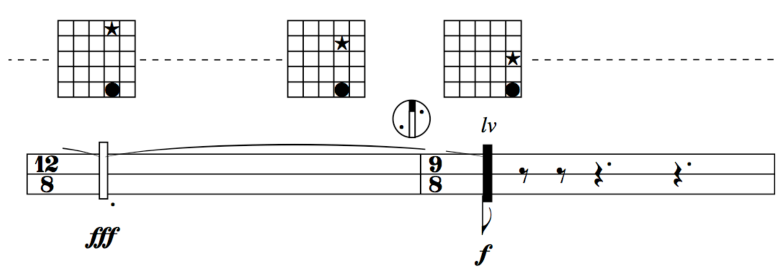
2. T-stick

1. The t-stick digital musical instrument (DMI) is a physical input device sensing where and how much of its surface is touched by the performer, along with detecting gestures such as: tilting, shaking, squeezing and twisting. This composition features the smallest model of the t-stick family, to date.
2. The voice of the t-stick (i.e., sound synthesis) is generated by a Mac Pro, two 2.8 GHz Quad-Core Intel, running Max/MSP 5 and Apple's software LogicPro 8. Both the Max/MSP patch and Logic project are provided by the composer. Refer to stage and technical set-ups for signal routing.
3. The music for the t-stick is written on a three-line staff, which corresponds to the touch sensing range of the instrument (Example B-2). The top and bottom lines respectively coincide with the top and bottom of the sensing range. The top of the range denotes the end that is furthest from the USB port, while the bottom indicates to the end closest to the port.



Example B-2. Three-line staff and notational symbols of the t-stick.

4. Generally speaking, the timbre of the t-stick is a result of both tilt and rotation; however several other factors are concomitantly contributing to the resulting sound (e.g., degree of surface contact; pressure applied to surface). Symbols (or tablature) appearing above the staff, instruct the performer on tilting and rotating the instrument (Example B-3).



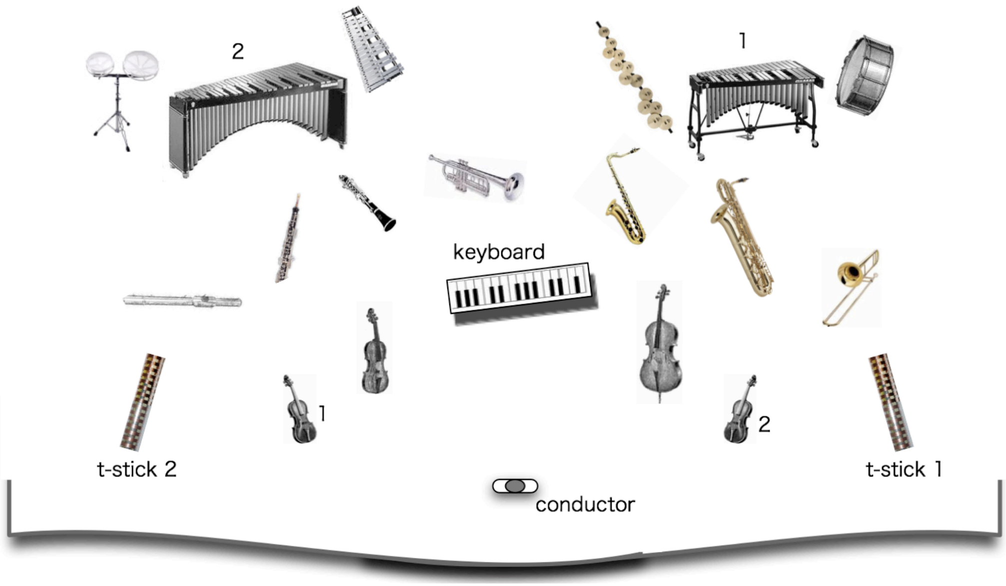
Example B-3. T-stick tablature, above the staff.

C – Staging and technical specifications

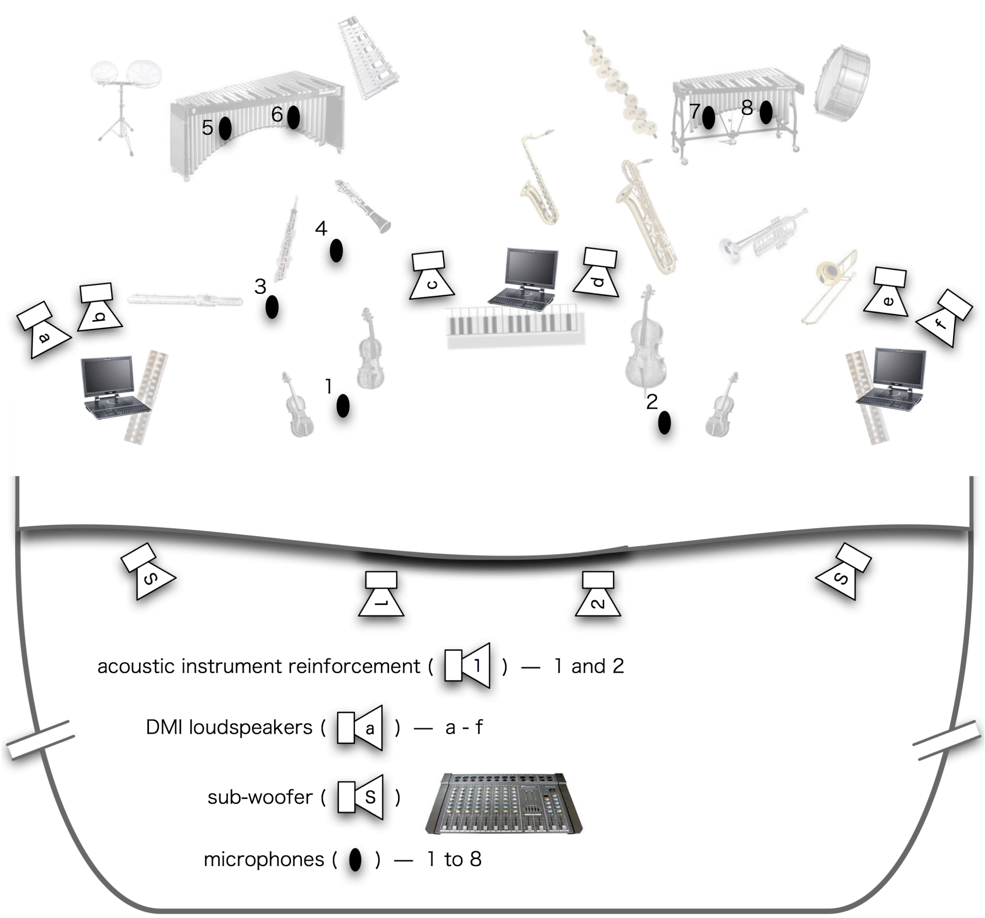
1. The stage set-up (see Example C-1, on page 130) instructs higher pitched wind instruments to be situated toward stage right, while lower pitched wind instruments are on stage left. This is also reflected in the placement of the viola, violoncello and some percussion instruments (e.g., roto toms are on stage right while bass drum is on stage left).
2. The pitch range of the centrally located keyboard is extensive, stretching from below and above the lowest and highest notes of the instrumental ensemble. The keyboard is placed in the centre to enhance its musical functions: grounding or anchoring almost the entire first half of the composition; conveying pitch material, which is simultaneously heard in the ensemble; performing solo.
3. The t-sticks are on the perimeters of the performance space, contrary to the keyboard. Their locations complement their musical gestures, which often have the striking effect of transposing the composite sound of the whole ensemble into an electroacoustic setting. In addition, the location of the t-sticks should provide adequate physical space for playing technique, which entails widely swinging and thrusting the instrument. The performers may choose to stand, while playing, although chairs should be provided.
4. The three on-stage computers generate sound for the three digital instruments: keyboard; t-stick 1 and 2. Each computer outputs a 2-channel signal (stereo). Each computer digitally delivers its signal via an audio interface (i.e., audio card), which is not shown in the technical set-up diagram (see Example C-2, on page 130). Use a basic audio interface from a recognised manufacturer (e.g., MOTU; RME; PreSonus; TC Electronic).
5. Output signal routing from computers/audio interfaces.
   - 5.1. Send signal from computers to the following
     - 5.1.1. On-stage DMI loudspeakers
     - 5.1.2. Global mix loudspeakers, in front of stage
     - 5.1.3. Sub-woofers
   - 5.2. On-stage loudspeakers are instrument specific and should be controlled by the performer—not from the mixing console.
   - 5.3. The purpose of the DMI loudspeakers is to provide the entire ensemble with some direct sound, coming from the DMIs.
6. Microphone signal routing
   - 6.1. Send microphone signals only to global mix loudspeakers.
   - 6.2. Generally speaking, microphones are used for sound reinforcement and not to increase the loudness of any instrument to an extreme decibel level.

6.3. It may not be necessary to reinforce all of the strings and the wind instruments (optional).

7. Global mix loudspeakers and sub-woofers
   7.1. These loudspeakers project sound from all microphone signals.
   7.2. Pan signals in order to reflect the spatial distribution of instruments on stage.
   7.3. Live sound control is an art; thus, time, thought, creativity and listening are required—before the concert—to achieve adequate levels.



Example C-1. Stage set-up.



Example C-2. Technical set-up.

D – Other DMI music by author

- A Hero's Conquest
  for SonicJumper '2003
  electro-acoustic interactive
  [50:00]

- ProjectVocals
  for SonicJumper '2005
  electro-acoustic interactive
  [15:00]

- Etude for HandSonic—CPR
  for HandSonic '2006
  [05:30]

- DANCING WITH A TIGER
  for tenor t-stick '2006
  [07:40]

- The One
  for tenor t-stick '2006
  [09:00]

- sounds between our minds
  for digital musical instruments '2008
  soprano t-stick, tenor t-stick, rulers
  [08:39]

- Everybody to the power of one
  for soprano t-stick sonor-jo '2008
  [06:17]

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Volume 2 – Musical Score

D. Andrew Stewart's

Catching
Air and the
S u p e r m a n

keyboard, digital t-sticks
and chamber orchestra

for Isabelle
et
l'enfant bleu

CONTENTS

The central figure in Catching Air and the Superman is the concept of leaping and its subsequent reiterations. If the initial action is a leap, then the trajectory of the consequent action is downward—a return to earth. In this way, this figure is both physical / corporeal (i.e., bouncing; hopping; bobbing; skipping; ricocheting; conveying upsurge and spasm) as well as aural (i.e., ascending / descending pitch; timbre described as cyclic, centric, undulating or forming a parabola).

Imagine the moment of maximum height—and maximum flight—in a single leap. 'Catching some air' is one idiom to express this instant in time: a moment of physical suspension interrupting gravitational force. Expressions of this instant can be found in the so-called extreme sports: skateboarding; snowboarding; kite-boarding; as well as BMX bicycle racing and freestyle. Moreover, this moment can also be measured in the concept of 'hang-time' in basketball. For instance, a long hang-time (the period of flight during a 'layup') reveals mastery of the skill and a seemingly superhuman control over body and nature. As a symbol, catching some air represents timelessness and a human endeavour to leave an indelible mark for all eternity. Furthermore, catching some air is not a satisfying action when executed only once—extreme sports are evidence of this. On the contrary, it is a repetitive action, in which the agent strives for ever greater superhuman power; thus the extent of power is endlessly increasing. This also implies that the power is unattainable—'Catching the superman' is unattainable.

The superman is metaphorically represented by the chord, or chordal sections, suggesting: closure, termination, the last act, the climax, the earth. It is the beginning and ending of any leap. The vehicle for air, on the other hand, is the resulting resonance from any chord, suggesting: sustain, pause, breathe, recurrence, eternity. Resonance is both real (i.e., sound reverberation) and simulated (i.e., composed material that repeats, undulates or sustains as a result of a chordal onset). Herein, one may perceive a dialectic in the relationship between the chord (the superman) and its resonance and repetition (air, eternal recurrence)—a dialogue inherent in the following:

All beings hitherto have created something beyond themselves: and ye want to be the ebb of that great tide, and would rather go back to the beast than surpass man?
Nietzsche, F. W. (1905). Thus spake Zarathustra. Zarathustra's Prologue. (T. Common, trans.) New York: Modern Library.

The preceding text is further expanded in my compositional analysis (Stewart 2009).

d. andrew stewart

INSTRUMENTATION

MIDI keyboard[1]

2 soprano t-sticks[1]

—chamber orchestra—

flute / piccolo
oboe
B♭ clarinet
B♭ tenor saxophone
E♭ baritone saxophone

B♭ or C trumpet
trombone

2 percussion

(1) amplified nickel vibraphone[2]; crotales; bass drum; roto toms in B and F♯; large bead almglocken in B[2]

(2) amplified marimba; glockenspiel; slap board[2]; large ratchet[2]; large bead almglocken in F♯[2]

2 amplified violins
amplified viola
amplified violoncello

[1] refer to digital instrument specifications

[2] refer to percussion specifications

PERFORMANCE NOTES

Permanent scordatura

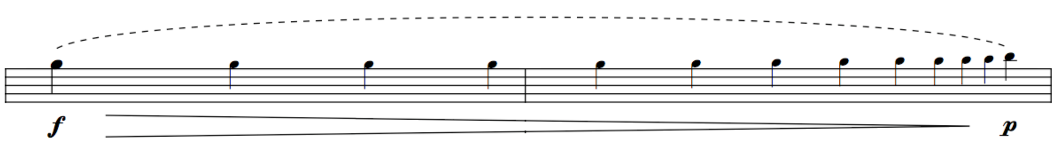
1. Most instruments are asked to detune either permanently (wind instruments) or momentarily (string instruments). The clarinet, baritone saxophone and pitched percussion instruments remain in tempered tuning throughout. Detuning is indicated in the score and parts.

Bouncing gesture

1. Emulate the rhythmic pattern of an accelerating ball coming to rest. In other words, freely accelerando, keeping the increasing velocity (i.e., speed / time) of attacks even.
2. In addition, the notation often indicates a slight upward frequency gliss. / bend. In these cases, smoothly go up in pitch toward the end of the bounce either by applying appropriate fingering or changing embouchure pressure or slide position, in the case of wind instruments.
3. Observe both articulation and dynamic indications, especially when diaphragm articulation is indicated (see below).

Diaphragm articulation (wind instruments)

1. A dashed slur designates diaphragm articulation.
2. Articulate note by contracting and expanding the diaphragm, and without articulating using the tongue. In other words, articulate only with a sudden change in air pressure.



Diaphragm articulation, combined with bouncing gesture

Quarter-tone accidentals (predominantly used in string parts)

1. quarter-tone sharp (𝄲)
2. quarter-tone flat (𝄳)

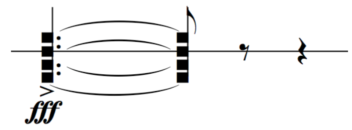
Sound reinforcement (see stage and technical set-ups)

1. The following instruments are reinforced through amplification: nickel vibraphone; marimba; all strings. Pan signals in order to reflect the spatial distribution of the instruments on stage.
2. If possible, also slightly reinforce the remaining acoustic instruments (and appropriately pan).

—notes on individual instruments—

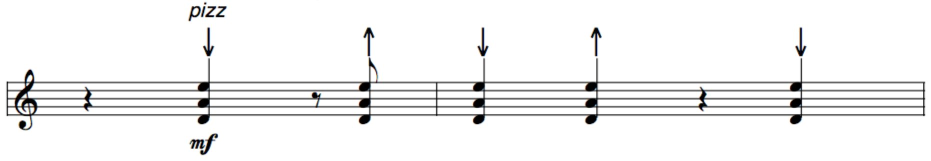
tenor and baritone saxophones

1. A chord consisting of square note heads indicates a multi-phonic. Follow the textual description and dynamic accompanying each multi-phonic.



violins and viola

1. Pick triple and quadruple-stops like a banjo. That is to say, hold the instrument laterally in front of the body, like a guitar, and strum.



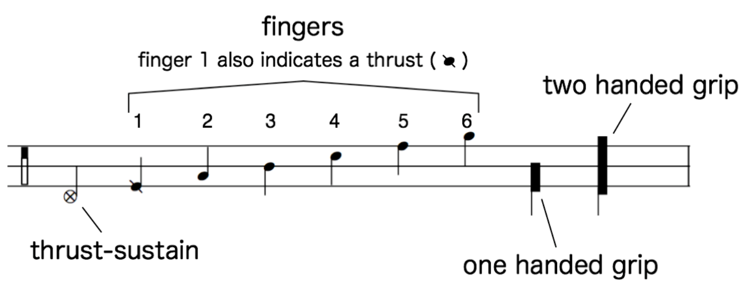
DIGITAL INSTRUMENT SPECIFICATIONS
AND PERFORMANCE NOTES

soprano t-sticks

1. The t-stick digital musical instrument (DMI) is a physical input device sensing where and how much of its surface is touched by the performer, along with detecting gestures such as: tilting, shaking, squeezing and twisting. This composition features the smallest model of the t-stick family, to date.

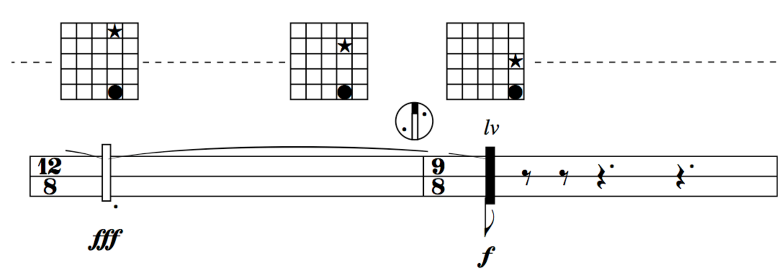
2. The voice of the t-stick (i.e., sound synthesis) is generated by a Mac Pro, two 2.8 GHz Quad-Core Intel, running Max/MSP 5 and Apple's software LogicPro 8. Both the Max/MSP patch and Logic project are provided by the composer. Refer to stage and technical set-ups for signal routing.

3. The music for the t-stick is written on a three-line staff, which corresponds to the touch sensing range of the instrument. The top and bottom lines respectively coincide with the top and bottom of the sensing range. The top of the range denotes the end that is furthest from the USB port, while the bottom indicates to the end closest to the port.



Three-line staff and notational symbols of the t-stick

4. Generally speaking, the timbre of the t-stick is a result of both tilt and rotation; however several other factors are concomitantly contributing to the resulting sound (e.g., degree of surface contact; pressure applied to surface). Symbols (or tablature) appearing above the staff, instruct the performer on tilting and rotating the instrument.



T-stick tablature

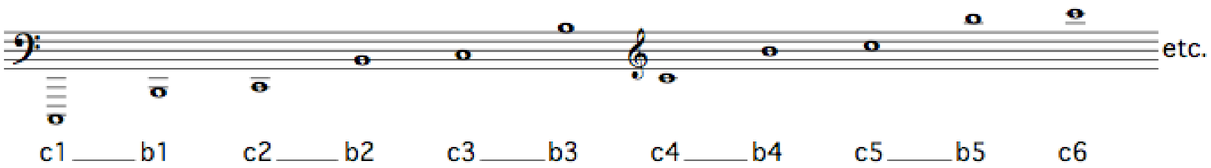
MIDI keyboard

1. Use an 88-key (a0 to c8, see note nomenclature below) MIDI keyboard with two sustain pedals (half pedal effects are not required). Choose an instrument that implements realistic piano action (e.g., Yamaha P-140), including properly weighted keys that simulate graded hammer action (i.e., keys in the lower register have a heavier touch than those in the upper register).

2. Sound synthesis directly from the keyboard (i.e., onboard instrumental voices) is not required; however, the instrument must have MIDI output capability, either via USB or a standard MIDI output port.

3. The voice of the MIDI keyboard (i.e., sound synthesis) is generated by a Mac Pro, two 2.8 GHz Quad-Core Intel, running Max/MSP 5 and Apple's software LogicPro 8. Both the Max/MSP patch and Logic project are provided by the composer. See stage and technical set-ups for signal routing.

4. Depressing a key determines pitch and loudness in addition to the timbre of the instrument. Instrumental timbre can be 'frozen', or 'locked', by depressing the left and right foot pedals. When this occurs, the produced timbre is a result of the last keys touched, with pedals released. The left pedal corresponds to key range a0 to b3, the right corresponds to range c4 to c8. A key that locks the timbre is referred to as a pedal-lock note, which is indicated in the score (e.g., b3 / a5), placed in a box next to the keyboard staff.



Note nomenclature

5. The symbols for pedalling are: Rp = right pedal; Lp = left pedal. In addition, bracketed symbols appear in the keyboard part (not in the score) under the first measure of each page, and serve to remind the player of which pedal(s) are currently depressed. Observe all foot pedal indications with precision. Improper use of the foot pedal may dramatically alter the sound of the instrument.

6. The MIDI keyboard sounds micro-tonally higher than written. Generally speaking, notes in the upper register of the keyboard are closer to tempered tuning than notes in the lower register. In addition, lower notes tend toward inharmonicity (i.e., percussive quality).

PERCUSSION SPECIFICATIONS

nickel vibraphone

1. Give the vibraphone a rattling timbre by attaching metal objects to the resonating bars and / or tubes. Each bar must continue to sound its distinct pitch, in addition to the added sound.
2. The tone of the instrument should be metallic and contain discrete noise elements—like a vibrating machine with loose components, loose screws, bars and plates. For instance, a 5¢ coin (the Canadian nickel) can be affixed with masking tape to each bar, at the end of the bar, or at a post (i.e., node). Alternatively, several large paperclips can be held against each bar with an elastic. Consider small link chains, as well.

slap board

1. A 2 X 4 inch wooden plank, approximately 3 feet, or more, in length.
2. Play the slap board by fixing one end to the stage floor and then 'slapping' the board against the floor by directly stepping on it.
3. Playing the slap board must also entail anticipating the conductors beat, due to the time needed for the board to actually travel from an upright position to the 'slap' position.
4. The end of the board that is initially touching the floor, may simply be wedged between the floor and the performer's foot. It does not have to be fastened to the floor with bolts. On the other hand, one might fasten the board to a piece of plywood, which would sit flush against the floor—like a very large slapstick.
5. Attaching a light rope to one end may facilitate lifting the board after each attack; however, be sure the rope does not get underneath the slap board.

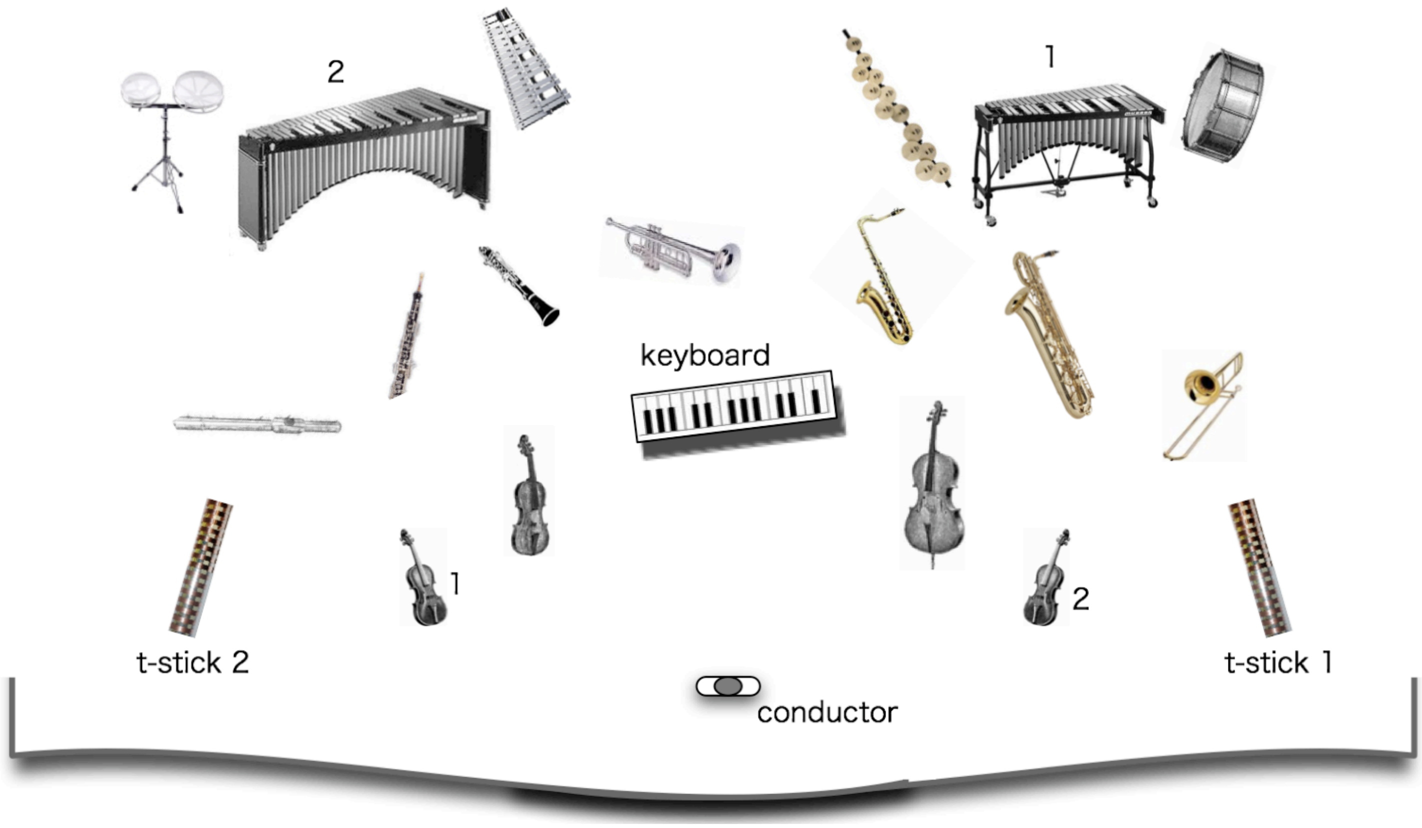
large bead almglocken

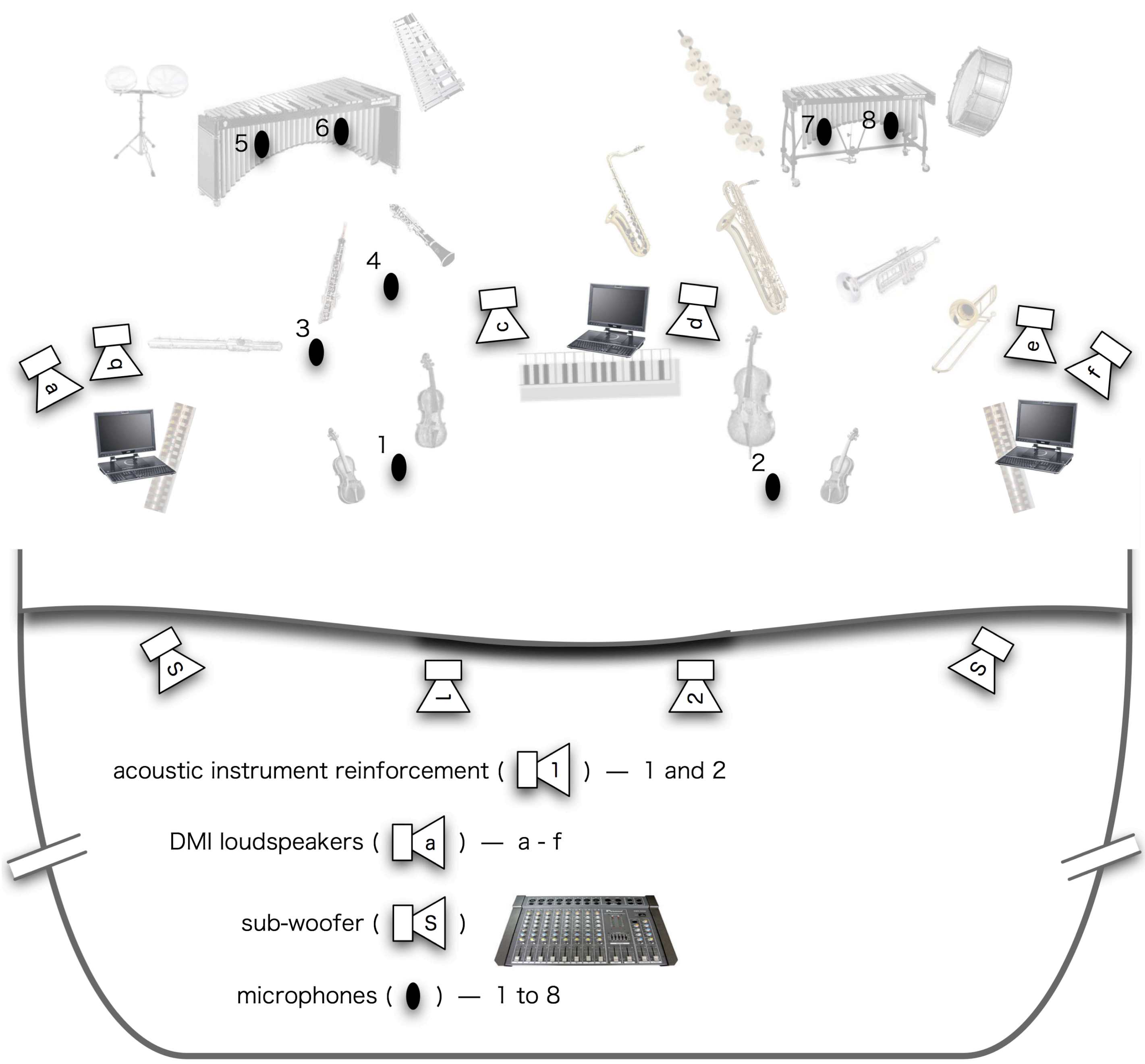
1. A very large almglocken holding several small and hard beads. Beads may be of any material; however, be careful not to choose a bead that damages the inside of the instrument.
2. Play the instrument like a rattle, with the opening of the almglocken toward the ceiling. Hold the instrument by its handle, high above the head. Shake the instrument trying to create as 'random' a sound as possible. In other words, allow the beads to jump around without creating any symmetrical rhythmic patterns.
3. If the almglocken is covered up by the composite ensemble sound, reinforce the sound with amplification. For instance, play the instrument through the same microphones that are used to amplify the vibraphone (percussion 1) or marimba (percussion 2).

large ratchet (percussion 2)

1. Achieve a loud dynamic by playing ratchet overhead, above the height of the orchestra. Affix to a wooden or metal resonator, if possible.
2. In addition to a resonator, or alternatively, reinforce the sound with amplification. For instance, play the instrument through the same microphones that are used to amplify the marimba.

STAGE AND TECHNICAL SET-UPS





—notes on set-up—

1. The stage set-up instructs higher pitched wind instruments to be situated toward stage right, while lower pitched wind instruments are on stage left. This is also reflected in the placement of the viola, violoncello and some percussion instruments (e.g., roto toms are on stage right while bass drum is on stage left).

2. The pitch range of the centrally located keyboard is extensive, stretching from below and above the lowest and highest notes of the instrumental ensemble. The keyboard is placed in the centre to enhance its musical functions: grounding or anchoring almost the entire first half of the composition; conveying pitch material, which is simultaneously heard in the ensemble; performing solo.

3. The t-sticks are on the perimeters of the performance space, contrary to the keyboard. Their locations complement their musical gestures, which often have the striking effect of transposing the composite sound of the whole ensemble into an electroacoustic setting. In addition, the location of the t-sticks should provide adequate physical space for playing technique, which entails widely swinging and thrusting the instrument. The performers may choose to stand, while playing; although chairs should be provided.

4. The three on-stage computers generate sound for the three digital instruments: keyboard; t-stick 1 and 2. Each computer outputs a 2-channel signal (stereo). Each computer digitally delivers its signal via an audio interface (i.e., audio card), which is not shown in the technical set-up diagram. Use a basic audio interface from a recognised manufacturer (e.g., MOTU; RME; PreSonus; TC Electronic).

5. Output signal routing from computers / audio interfaces
5.1. Send signal from computers to the following
   (A) On-stage monitors
   (B) DMI loudspeakers up stage
   (C) Global mix loudspeakers
   (D) Sub-woofers
5.2. On-stage monitors are instrument specific and should be controlled by the performer—not from the mixing console. In the case of the keyboard, convert the stereo signal into mono before sending to the monitor.
5.3. The purpose of the DMI loudspeakers is to provide the entire ensemble with some direct sound, coming from the DMIs. Pan signals in order to reflect the spatial distribution of the keyboard and t-sticks on stage.

6. Microphone signal routing
6.1. Send microphone signals only to global mix loudspeakers
6.2. Generally speaking, microphones are used for sound reinforcement and not to increase the loudness of any instrument to an extreme decibel level.
6.3. It may not be necessary to reinforce the wind instruments (microphones 9 to 15 in the technical set-up diagram).

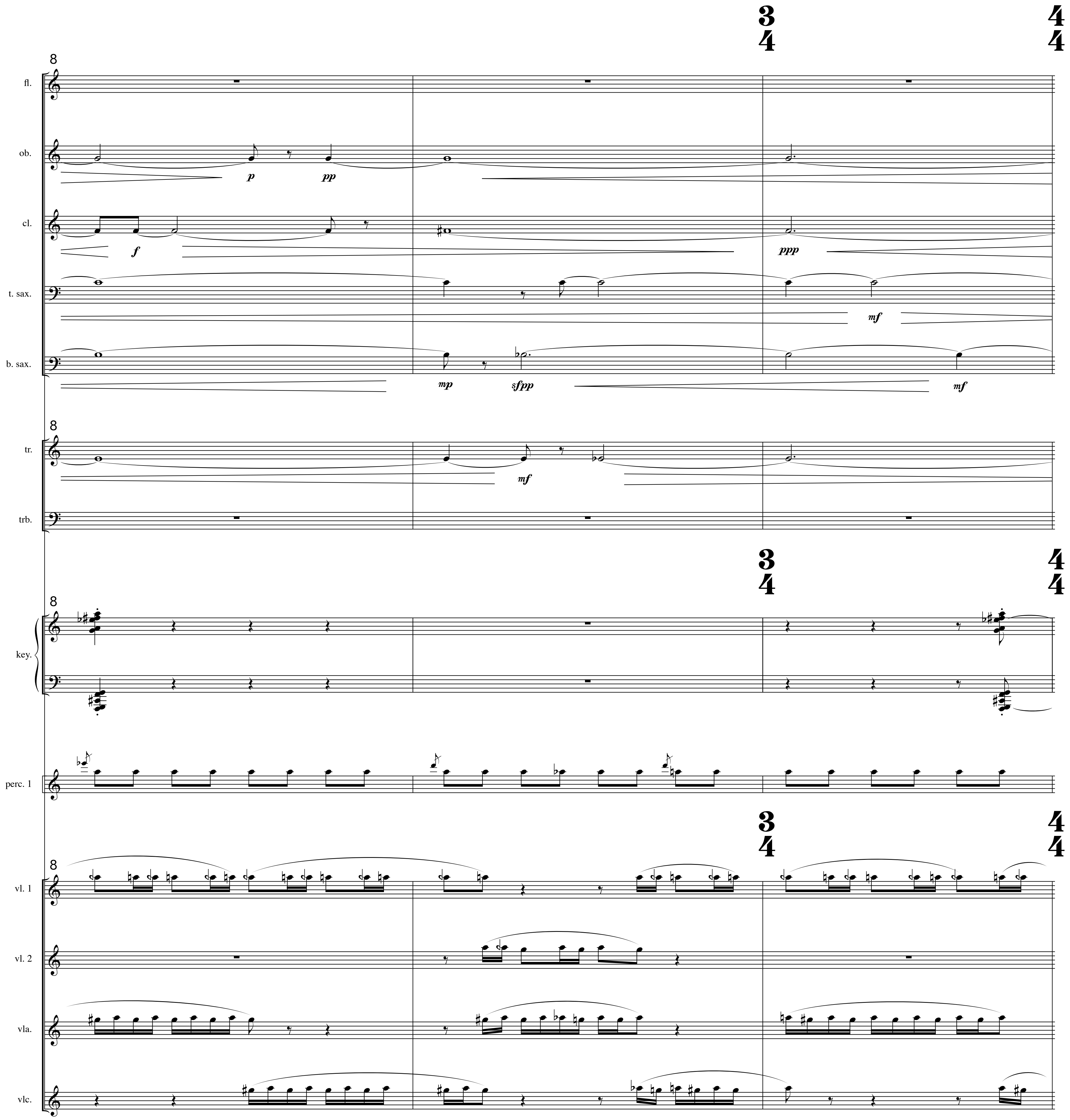
7. Global mix loudspeakers and sub-woofers
7.1. These loudspeakers project sound from all microphone signals and DMIs (sub-woofers are only for DMIs).
7.2. Pan signals in order to reflect the spatial distribution of instruments on stage.
7.3. Live sound control is an art; thus, time, thought, creativity and listening are required—before the concert—to achieve adequate levels.

MUSICAL SCORE

duration 15 minutes 15 seconds

♩ = 144
Nontransposing Score
Flute / Piccolo
Flute
Permanent scordatura. Up to 1/4 tone higher. Acquire detuning by adjustng head joint.
Oboe
Permanent scordatura. Down to 1/4 tone lower. Acquire detuning by constructing an appropriate reed and adjustng reed tube.
Accelerate like a bouncing ball coming to rest.
Clarinet
Accelerate like a bouncing ball coming to rest.
Tenor Saxophone
Permanent scordatura. Down to 1/4 tone lower. Acquire detuning by adjustng mouthpiece and gooseneck.
Baritone Saxophone
Accelerate like a bouncing ball coming to rest.
Trumpet
Permanent scordatura. Down to 1/4 tone lower. Acquire detuning by adjustng main tuning slide, as well as using the third valve, when possilbe.
Laid-back, fat big band sound. Not brassy.
Trombone
Permanent scordatura. Down to 1/4 tone lower. Acquire detuning by adjustng main tuning slide and lengthening slide positions.
MIDI Keyboard
Pedal-lock notes
b3 / a6
The MIDI keyboard sounds microtonally higher than written. Generally speaking, notes in the upper register of the keyboard are closer to tempered tuning than notes in the lower register.
Rp
Lp
D. Andrew Stewart's
Catching
Air and the
Superman
Soprano T-Stick 1
Soprano T-Stick 2
Percussion 1
Nickel Vibraphone (hard yarn mallets)
half-pedal
Percussion 2
Violin 1
1/4 tone flat
Violin 2
Viola
Violoncello


fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
1/4 tone sharp ( ) 1/4 tone flat ( )


8
fl.
ob.
p
pp
cl.
f
ppp
t. sax.
mf
b. sax.
mp
sfpp
mf
tr.
mf
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.


A
11
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
f
pp
p


14
fl.
ob.
p
cl.
p
t. sax.
mf
b. sax.
mf
14
tr.
mf
p
sfp
trb.
14
key.
perc. 1
14
vl. 1
cresc
vl. 2
cresc
vla.
vlc.
cresc


18
B
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.


22
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
cresc
cresc
cresc


26
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
sub p
cresc


C
30
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
mf
fp
p
f
sub p
cresc


34
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
sub p
cresc

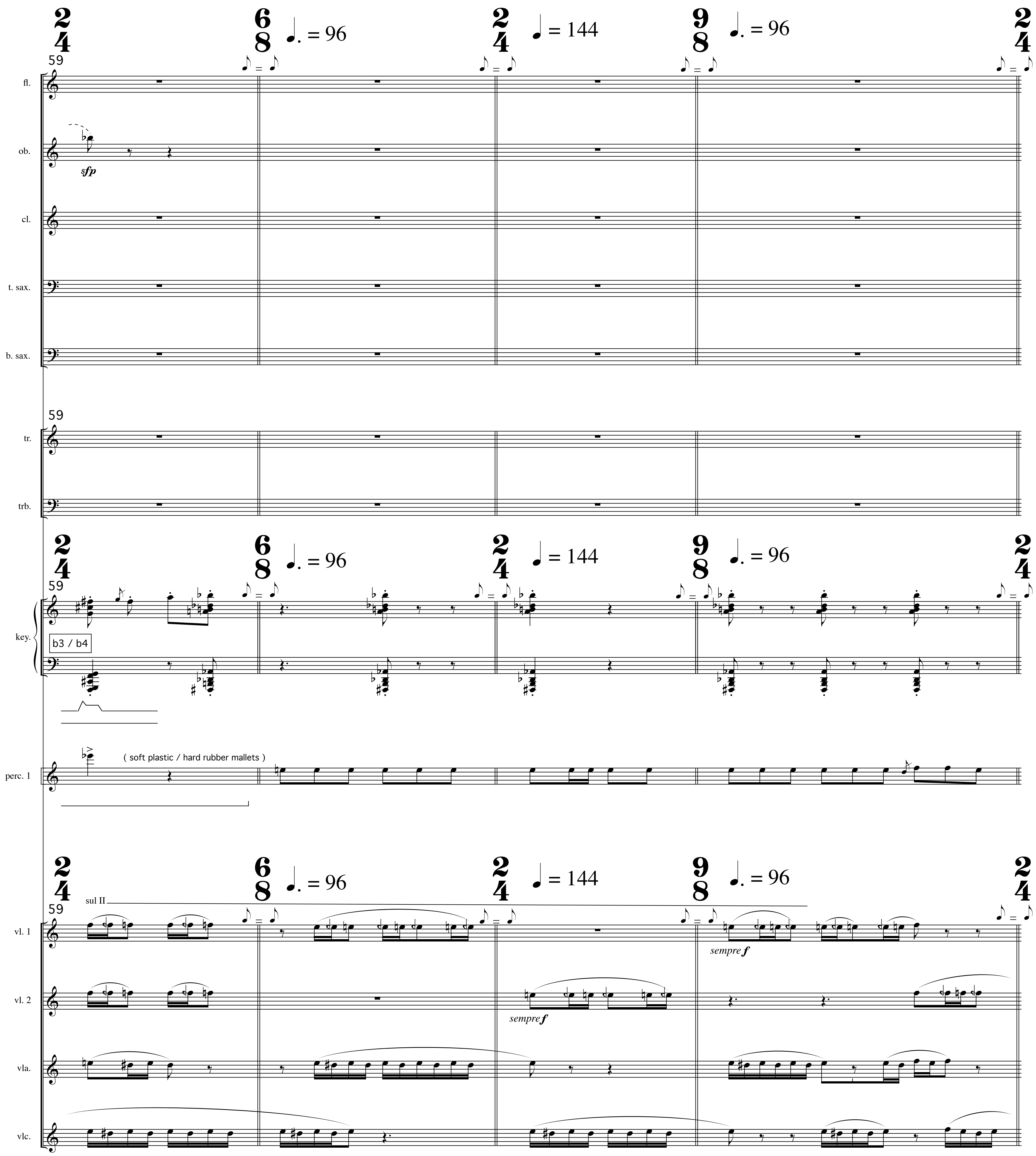

D
39
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
Glockenspiel (brass mallets)
perc. 2
lv
vl. 1
vl. 2
vla.
vlc.


43
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
sub p
1/4 tone flat
1/4 tone sharp


E
47
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
1/4 tone flat


51
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
diaphragm articulation
diaphragm articulation
sub p
sub pp
8va


55
fl.
ob.
cl.
t. sax.
b. sax.
diaphragm articulation
f
sub p
sfp
f p
pp f
tr.
trb.
fp
key.
Rp
Lp
perc. 1
half-pedal
perc. 2
vl. 1
vl. 2
vla.
vlc.
sempre f


♩. = 96
♩ = 144
♩. = 96
59
fl.
ob.
sfp
cl.
t. sax.
b. sax.
59
tr.
trb.
59
key.
b3 / b4
perc. 1
(soft plastic / hard rubber mallets)
59
sul II
vl. 1
sempre f
vl. 2
sempre f
vla.
vlc.


= 144
F
63
fl.
ob.
cl.
t. sax.
b. sax.
ff
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.


9/8 ♩. = 96
3/4 ♩ = 144
67
fl.
ob.
cl.
t. sax.
b. sax.
p
mf
8va
tr.
trb.
f
key.
perc. I
vl. 1
vl. 2
vla.
vlc.
sul II
sempre f


70
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
sul II


74
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
mf f
mf f
mf sfz mf
p
p sfz mf
p sfz mf
p sfz mf


G
rit
Slowy ritardando to mm.83
77
fl.
ob.
cl.
t. sax.
b. sax.
diaphragm articulation
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.


80
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
♩ = 87
♩. = 58
sempre f
1/4 tone sharp


H
= 58 [= 288]
= 144
= 58
84
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
sempre f
Accelerate like a bouncing ball coming to rest.
1/4 tone sharp
8va
sfz
mf
mp
p
pp
f
sfp

= 144
90
fl.
ob.
cl.
t. sax.
b. sax.
Accelerate like a bouncing ball coming to rest.
Use valve slide if possible, in order to achieve a slight upward frequency bend toward the end of the note.
tr.
diaphragm articulation
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.

95
32
88
♩. + ♩ = 58
fl.
ob.
cl.
t. sax.
b. sax.
Accelerate like a bouncing ball coming to rest.
Accelerate like a bouncing ball coming to rest.
Accelerate like a bouncing ball coming to rest.
sfp
mf
tr.
trb.
mp
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
senza vibrato
gradually sul ponticello
4
4


♩ = 144
100
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
t-stick 1
t-stick 2
cresc
perc. 1
vl. 1
vl. 2
vla.
vlc.
Accelerate like a bouncing
ball coming to rest. (on-string)
sul ponticello


104
fl.
ob.
cl.
Breathy, airy tone
ppp
pp
ppp
pp
ppp
t. sax.
Breathy, airy tone
sempre pp
ppp
b. sax.
Breathy, airy tone
sempre pp
104
tr.
trb.
104
key.
Gradually move to next position
t-stick 1
pp
ppp
pp
ppp
pp
ppp
t-stick 2
perc. 1
104
vl. 1
vl. 2
vla.
vlc.
p
mp


110
fl.
ob.
cl.
ppp p ppp
Gradually move to an extremely breathy sound
t. sax.
pp
pp ppp
pp
Gradually move to an extremely breathy sound
b. sax.
pp ppp
pp
110
tr.
Straight mute
trb.
sempre pp p pp
p pp
110
key.
t-stick 1
p
t-stick 2
perc. 1
110
vl. 1
vl. 2
vla.
vlc.
p mf p mf p mp


117
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
No mute
key.
b3 / b4
t-stick 1
t-stick 2
perc. 1
Nickel Vibraphone (soft plastic / hard rubber mallets)
vl. 1
vl. 2
vla.
vlc.
sul ponticello
modo ordinario
= 96

4/4 ♩ = 144
9/8 ♩. = 96
6/8
121
fl.
ob.
cl.
t. sax.
b. sax.
pp
pp
pp
f
tr.
trb.
mf
cuivré
fff
ff
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
mf


rit
124
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.


K
Slowly ritardando to mm.142
128
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
f
p
pp
mf
sfz
cresc


131
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
mf
pp
f


134
fl.
ob.
cl.
t. sax.
b. sax.
134
tr.
trb.
134
key.
perc. 1
134
vl. 1
vl. 2
vla.
vlc.
sfp
f
mf
ff
4/4
3/4


137
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
Accelerate like a bouncing ball coming to rest.
Accelerate like a bouncing ball coming to rest.
Accelerate like a bouncing ball coming to rest.
Sing either notated pitch or octave higher (growl).
marcato
marcato

= 90
= 144
142
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
b3
Rp
Lp
perc. 1
vl. 1
vl. 2
vla.
vlc.
sub pp
sul II


148
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
cluster
g3
Lp
sul II


M
153
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
cluster
sffz
pp
f
fp
ff
p


158
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
sffz
p
ff
pp
f
f3
Lp

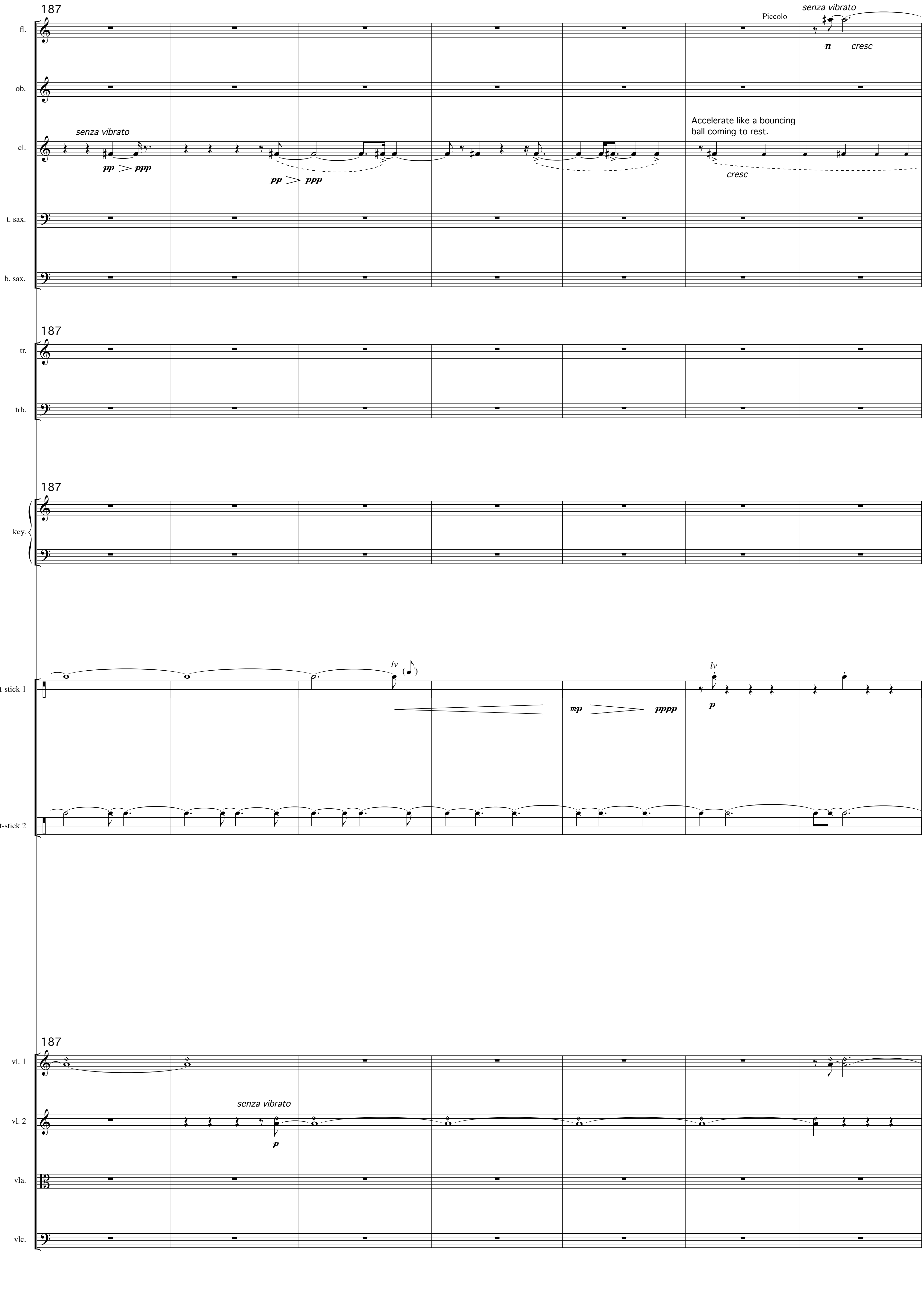

163
N
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
Straight mute
Cup mute
key.
e3
Lp
perc. 1
vl. 1
vl. 2
vla.
vlc.

3/4
168
2+2+3/8
6/8
♩. = 96
accel Slowly accelerando to mm.185
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
pp
p
sffz
ff
f
fp
mf
sfz


173
fl.
ob.
cl.
t. sax.
b. sax.
173
tr.
trb.
Sing either notated pitch or octave higher (growl).
173
key.
Lp
perc. 1
173
vl. 1
vl. 2
sul II
vla.
vlc.
sul IV


178
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
vl. 1
vl. 2
vla.
vlc.
♩. = 152
♩ = 114
sffz
pp
sfz
p
mf
f
ff


O ♩ = 144
183
fl.
Piccolo
ob.
cl.
finger gliss.
High-pitched multiphonic (shriek)
t. sax.
b. sax.
tr.
growl
trb.
key.
f♯3
Lp
No low frequencies
(i.e., cut-off frequency is high)
Both hands within the bottom half of the sensing range
Capacitive sensors away from body
t-stick 1
1/4 tone sharp (♯)
Both hands within the top half of the sensing range
Capacitive sensors pointing down
t-stick 2
perc. 1
senza vibrato
sub p
vl. 1
vl. 2
vla.
sul IV
vlc.

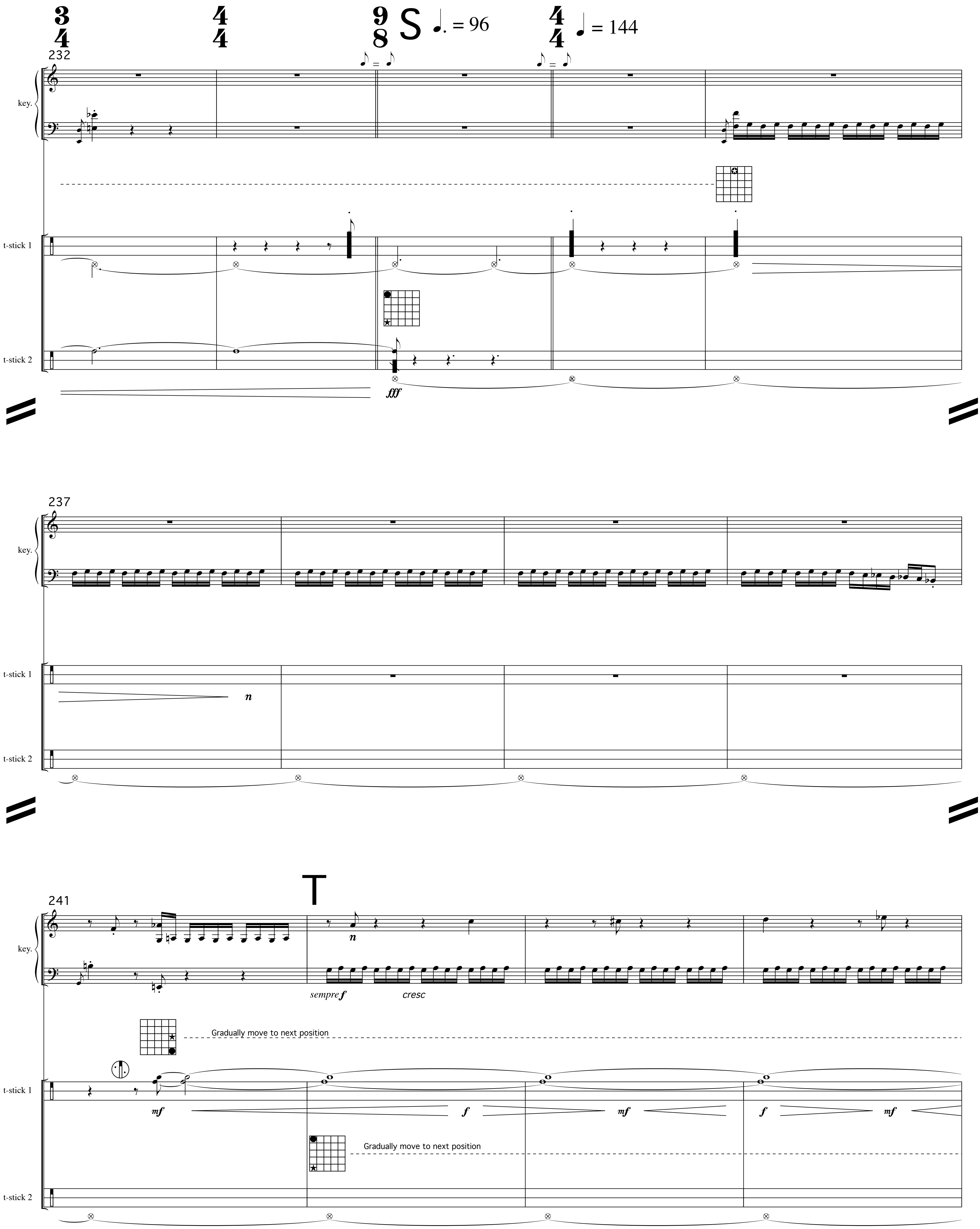

187
fl.
ob.
cl.
t. sax.
b. sax.
Piccolo
senza vibrato
n
cresc
senza vibrato
pp > ppp
pp > ppp
Accelerate like a bouncing
ball coming to rest.
cresc
187
tr.
trb.
187
key.
lv
lv
t-stick 1
mp
pppp
p
t-stick 2
187
vl. 1
vl. 2
senza vibrato
p
vla.
vlc.

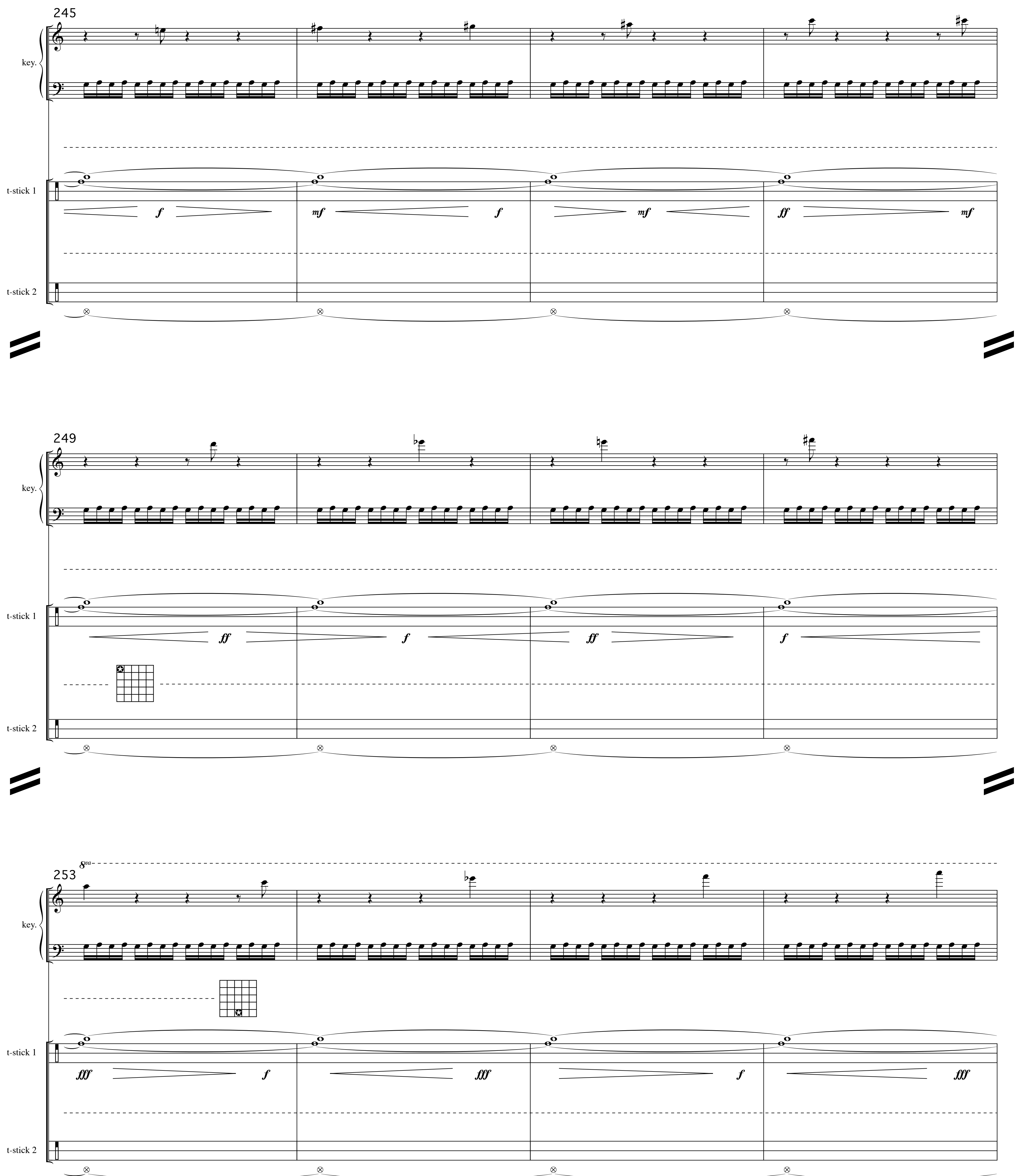

P
194
fl.
pp
ob.
cl.
p
pp
p
t. sax.
b. sax.
194
No mute
senza vibrato
tr.
n
pp
trb.
P
194
key.
t-stick 1
1/4 tone flat
Gradually move to next position
vibrato
t-stick 2
P
194
vl. 1
vl. 2
vla.
vlc.

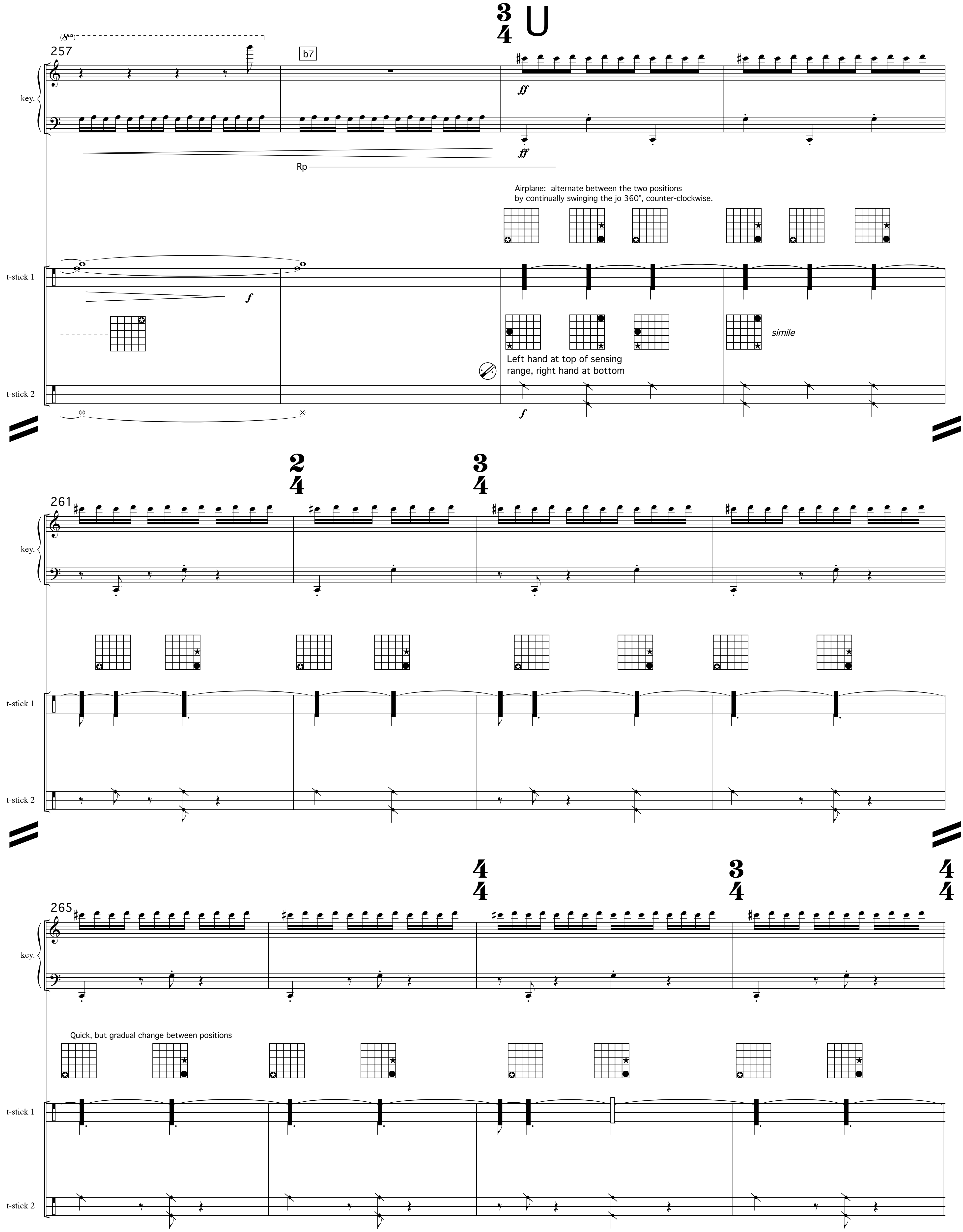

202
fl.
ppp
pp
senza vibrato
tempered tuning
ob.
n
mp
cl.
pp
p
pp
ppp
p
t. sax.
p
b. sax.
202
tr.
p
pp
p
pp
p
trb.
202
key.
Gradually move to next position
t-stick 1
To facilitate position, lift instrument over right shoulder.
t-stick 2
mf
202
vl. 1
pp
vl. 2
senza vibrato
vla.
n
mf
pp
senza vibrato
vlc.
p
p

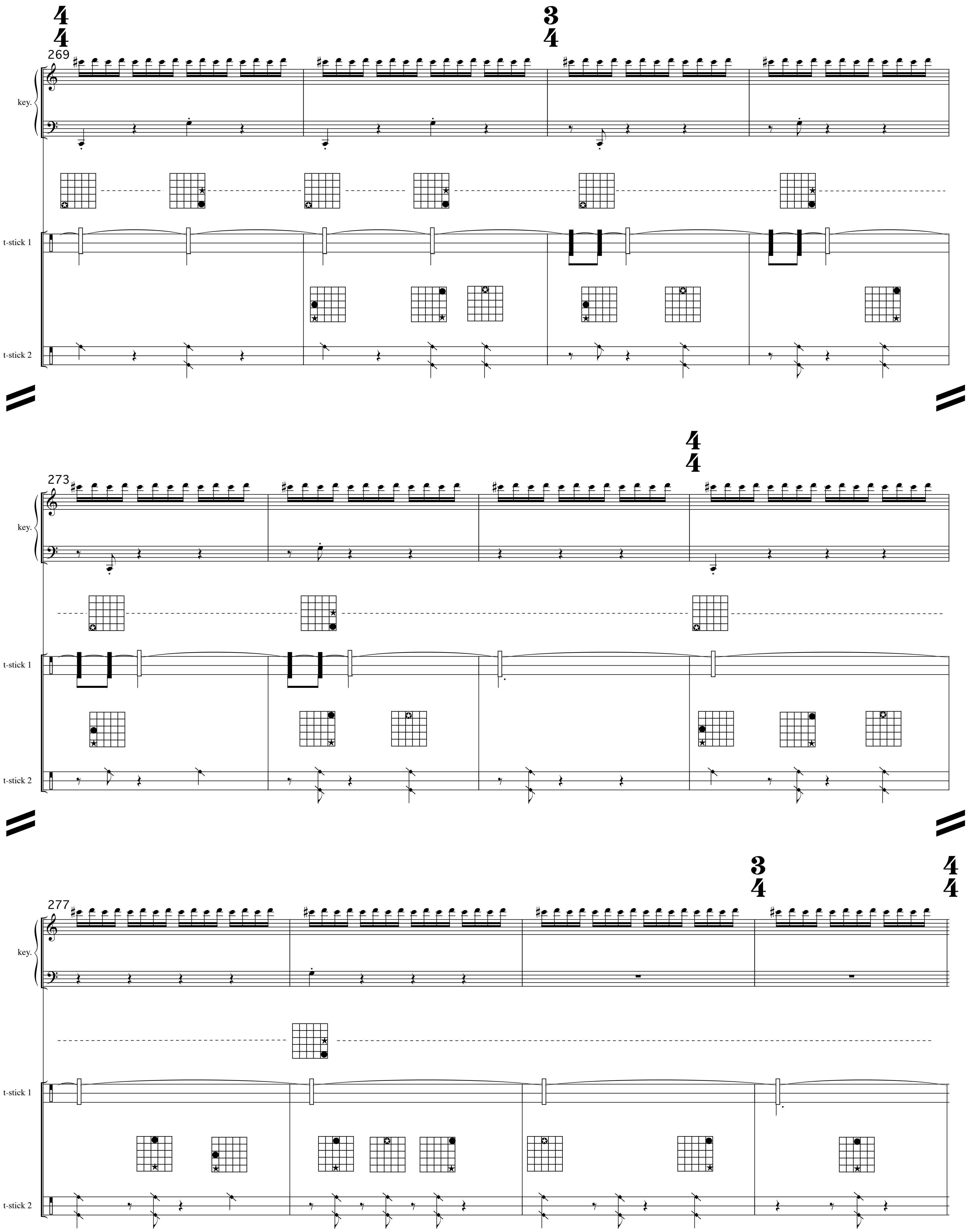

Q
209
fl.
ob.
scordatura
cl.
t. sax.
b. sax.
tr.
trb.
key.
t-stick 1
lv
Capacitive sensors toward body
t-stick 2
vl. 1
vl. 2
vla.
vlc.

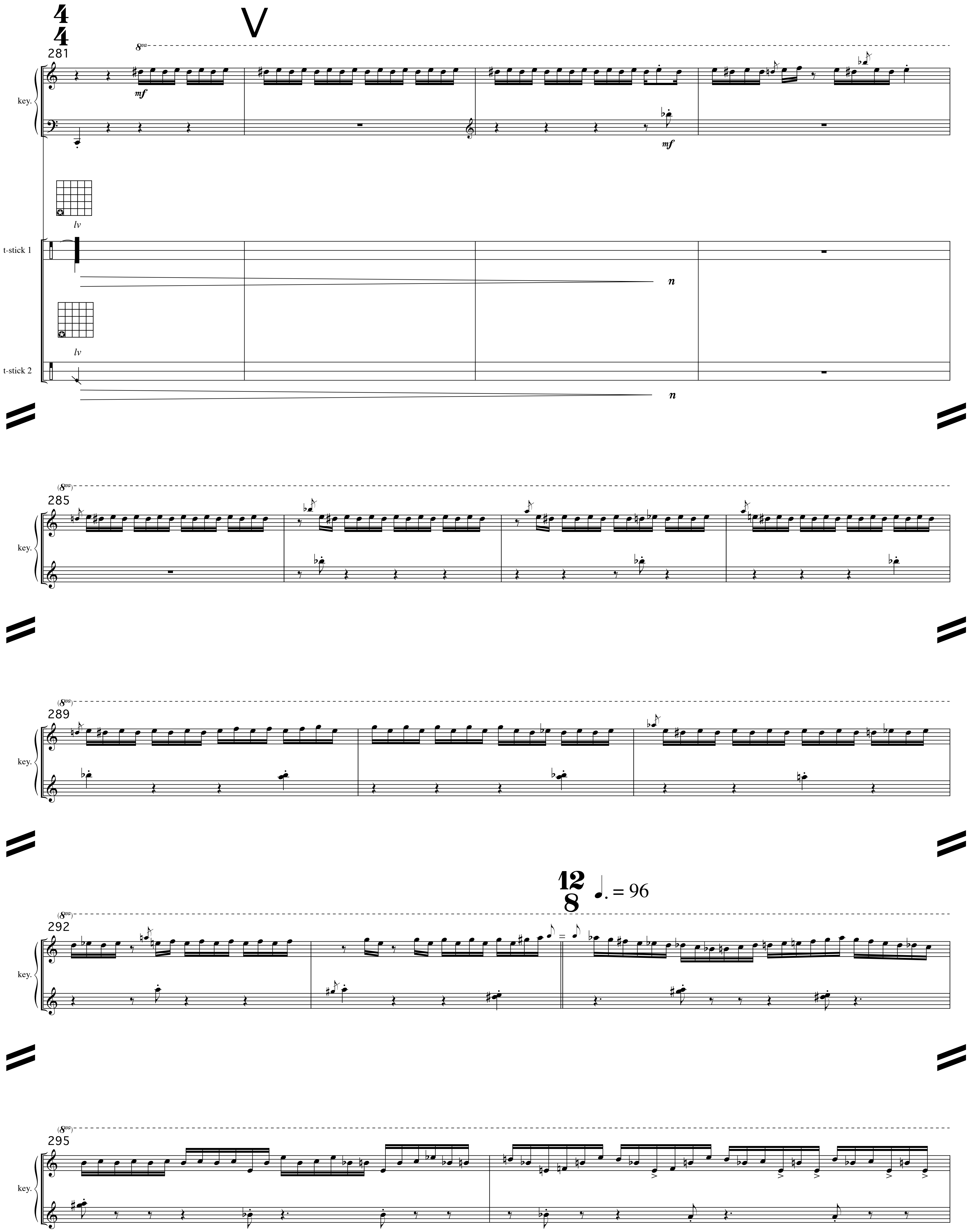

216
♩. = 96
♩ = 144
key.
t-stick 1
t-stick 2
f
ff
fff
Gradually move to next position
R
222
227
lv
decresc

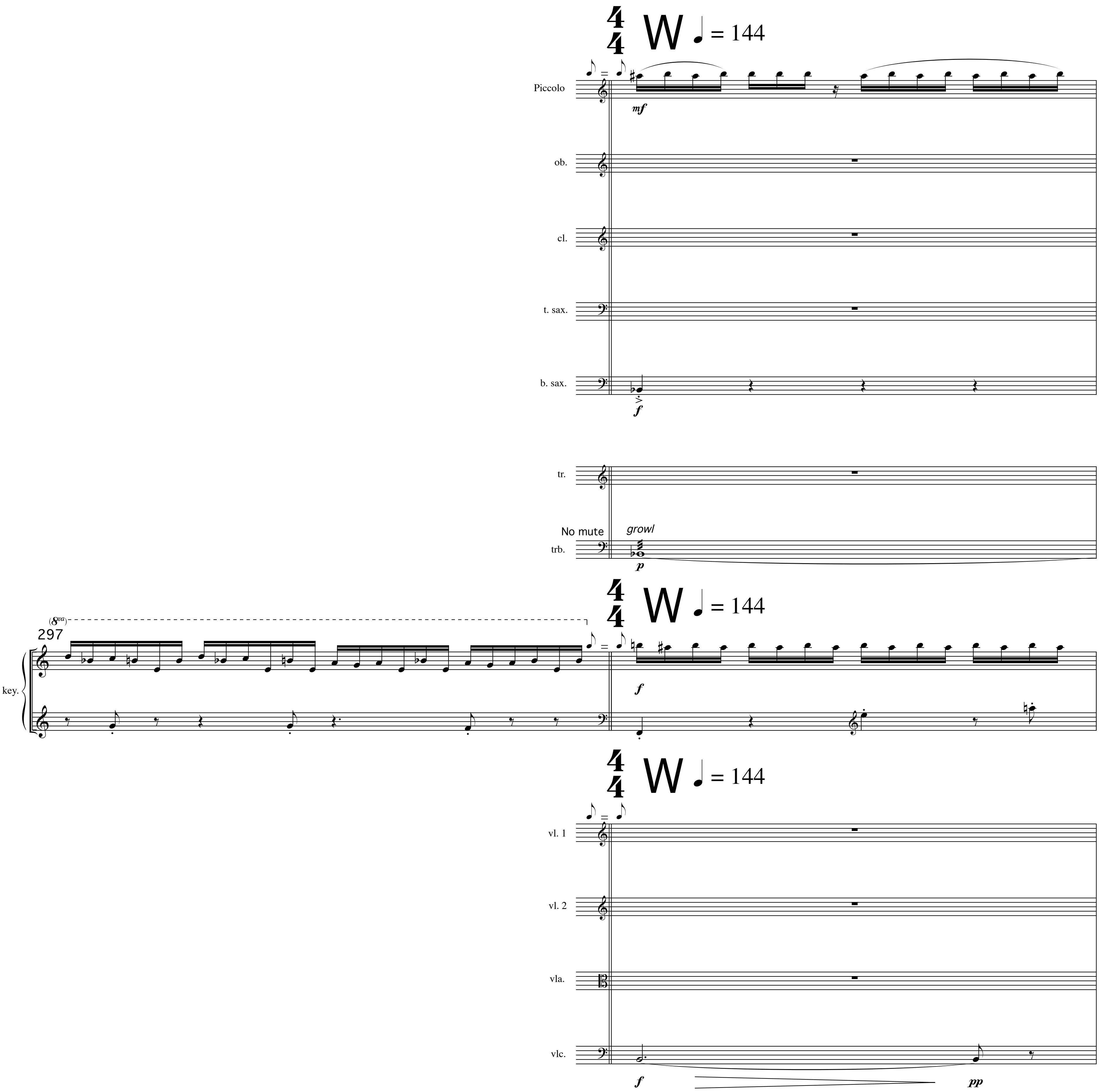

S
= 96
= 144
232
key.
t-stick 1
t-stick 2
fff
237
n
T
241
sempre f
cresc
Gradually move to next position
mf
f
Gradually move to next position


245
key.
t-stick 1
f
mf
f
mf
ff
mf
t-stick 2
249
key.
t-stick 1
ff
f
ff
f
t-stick 2
253
8va
key.
t-stick 1
fff
f
fff
f
fff
t-stick 2


U
257
b7
key.
ff
ff
Rp
Airplane: alternate between the two positions
by continually swinging the jo 360°, counter-clockwise.
t-stick 1
f
Left hand at top of sensing
range, right hand at bottom
simile
t-stick 2
f
261
265
Quick, but gradual change between positions


269
key.
t-stick 1
t-stick 2
273
key.
t-stick 1
t-stick 2
277
key.
t-stick 1
t-stick 2


4
4
V
8va
281
key.
mf
lv
t-stick 1
n
t-stick 2
285
289
292
12
8
♩. = 96
295


W ♩ = 144
Piccolo
mf
ob.
cl.
t. sax.
b. sax.
f
tr.
No mute
growl
trb.
p
(8va)
297
key.
f
vl. 1
vl. 2
vla.
vlc.
f
pp


299
fl.
ob.
cl.
t. sax.
b. sax.
299
tr.
trb.
299
key.
299
8va
vl. 1
mf
8va
vl. 2
mf
vla.
vlc.


302
fl.
ob.
mf
cl.
f
t. sax.
b. sax.
302
tr.
trb.
302
key.
302
8va
vl. 1
vl. 2
vla.
mp
p
vlc.


306
3 4
6 8 X ♩. = 96
12 8
Flute
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
cluster
Crotales
(hard plastic)
lv
mf
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.


12
8
310
fl.
ob.
cl.
t. sax.
b. sax.
310
tr.
trb.
12
8
310
key.
perc. 1
perc. 2
12
8
310
vl. 1
vl. 2
vla.
vlc.


312
fl.
ob.
cl.
t. sax.
b. sax.
312
tr.
trb.
312
key.
perc. 1
perc. 2
312
vl. 1
vl. 2
vla.
vlc.
3
4
3
4
3
4


Y ♩ = 144
314
Flute
fl.
ob.
cl.
t. sax.
b. sax.
Cup mute (loose fit)
tr.
growl
trb.
key.
perc. 1
perc. 2
Hold and pick like a banjo
pizz
simile
vl. 1
vl. 2
vla.
vlc.


318
fl.
ob.
cl.
t. sax.
p
b. sax.
318
tr.
trb.
318
key.
perc. 1
perc. 2
Glockenspiel (hard plastic)
lv
p
318
vl. 1
vl. 2
vla.
vlc.
pp
mp
p


322
fl.
ob.
cl.
t. sax.
mp
pp
mp
b. sax.
f
322
tr.
mf
growl
trb.
p
322
key.
perc. 1
perc. 2
322
vl. 1
vl. 2
vla.
vlc.
pp
p
pp


Z
326
fl.
ob.
cl.
p
t. sax.
pp
f
b. sax.
f
326
tr.
mf
growl
trb.
mp
Z
326
key.
perc. 1
perc. 2
Z
326
vl. 1
vl. 2
vla.
vlc.
n

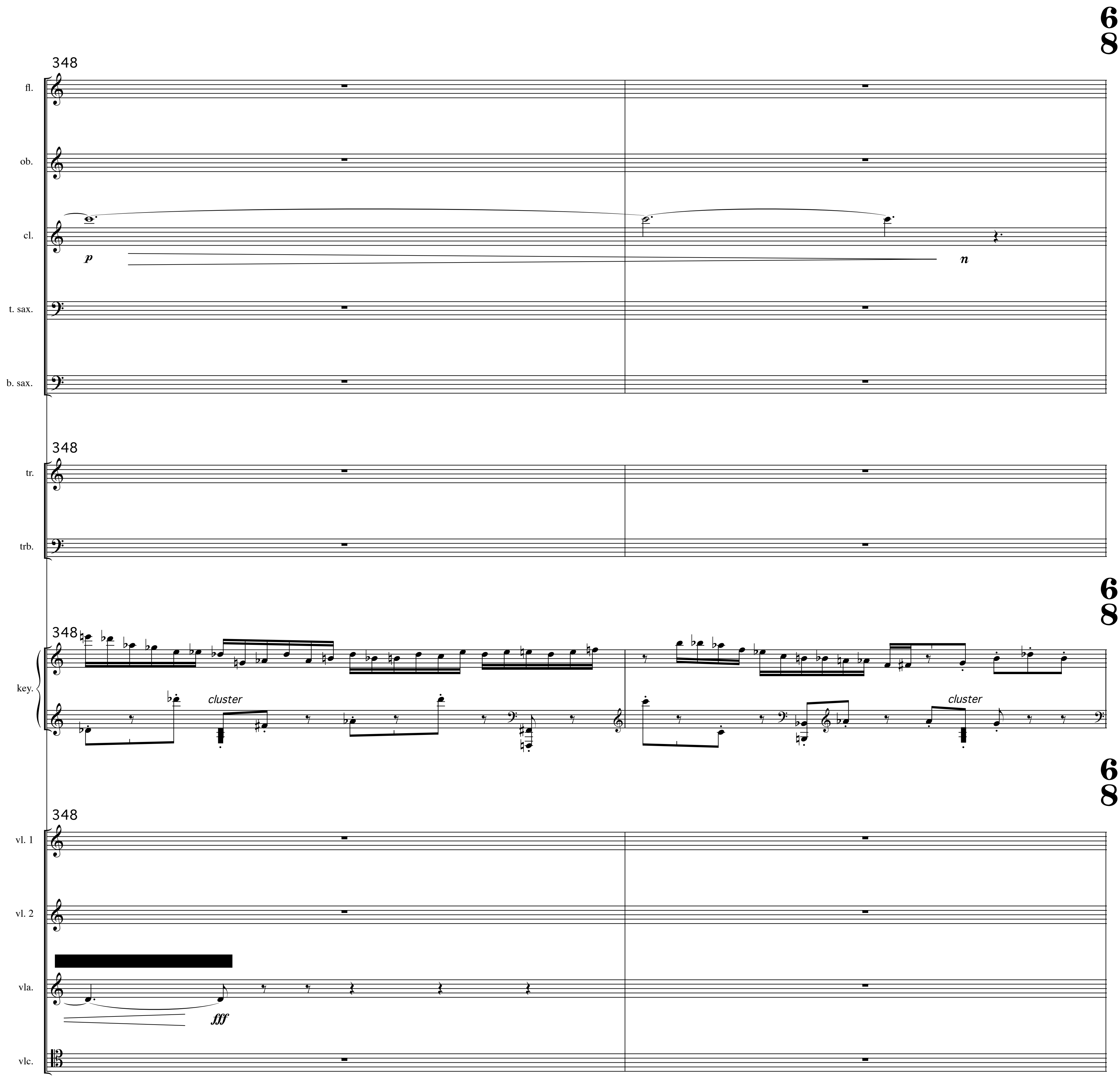

330
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
Straight mute
key.
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
pizz
mp
p
f
fp
mf


Aa
334
fl.
ob.
cl.
t. sax.
b. sax.
334
No mute
tr.
trb.
Aa
334
f5
key.
Rp
perc. 1
Marimba (hard yarn mallets)
perc. 2
Aa
334
arco
vl. 1
sempre f
vl. 2
vla.
arco
vlc.


338
fl.
ob.
flutter tongue
cl.
t. sax.
b. sax.
338
tr.
trb.
338
key.
perc. 1
perc. 2
338
vl. 1
vl. 2
sempre f
vla.
sempre f
vlc.


342
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
simile
simile
mf
f
mp
p
9
8

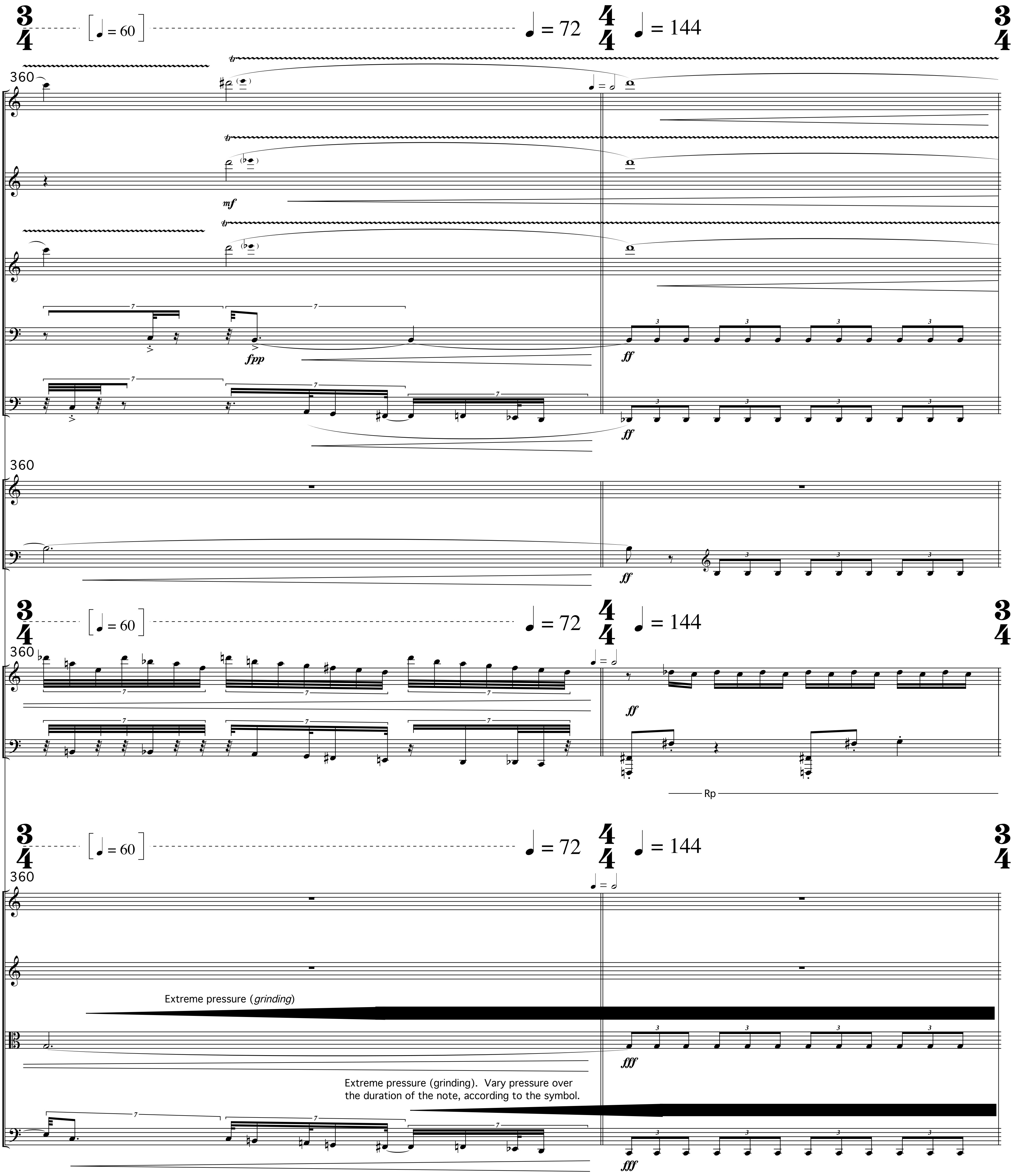
9/8 ♩. = 96
6/8
12/8 Bb
345
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
c8
15ma
Rp
perc. 1
(metal mallets)
lv
perc. 2
molto vibrato
vl. 1
vl. 2
Extreme pressure (grinding). Vary pressure over the duration of the note, according to the symbol.
arco
vla.
pizz
vlc.


6
8
348
fl.
ob.
cl.
p
n
t. sax.
b. sax.
348
tr.
trb.
6
8
348
key.
cluster
cluster
6
8
348
vl. 1
vl. 2
vla.
fff
vlc.


accel
350
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
vl. 1
vl. 2
vla.
vlc.

♩. = 160 [♩.+♩ = 96] 2/4 ♩ = 96
9/8 Cc ♩. = 96
12/8
355
fl.
ob.
cl.
t. sax.
b. sax.
f
tr.
trb.
No mute
VII
fp
cresc
key.
vl. 1
vl. 2
vla.
mf
arco
vlc.

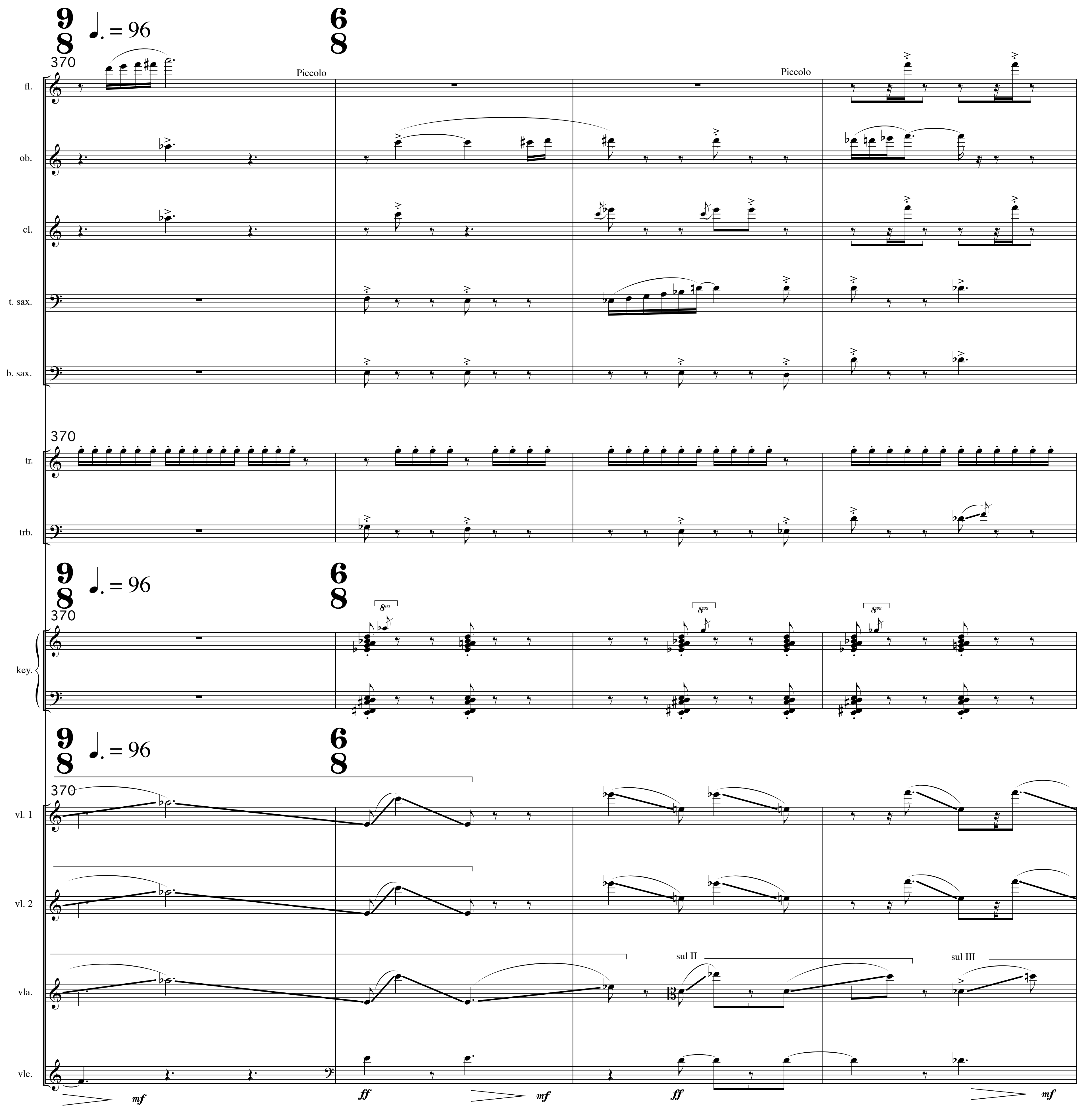

12
8
accel
= 120
3
4
358
fl.
ob.
cl.
t. sax.
b. sax.
p cresc
tr.
trb.
key.
vl. 1
vl. 2
vla.
vlc.
f



360
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
vl. 1
vl. 2
vla.
vlc.
= 60
= 72
= 144
mf
fpp
ff
fff
Rp
Extreme pressure (grinding)
Extreme pressure (grinding). Vary pressure over the duration of the note, according to the symbol.


Dd
362
fl.
ob.
cl.
t. sax.
b. sax.
tr.
Laid-back, fat big band sound. Not brassy.
trb.
key.
f♯3
Lp
vl. 1
vl. 2
vla.
vlc.
sul II
gliss
arco


366
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
vl. 1
vl. 2
vla.
vlc.
Gliss. over more than one string
ff
cresc



370
= 96
Piccolo
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
vl. 1
vl. 2
vla.
vlc.
sul II
sul III
mf
ff


374
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
vl. 1
vl. 2
vla.
vlc.
♩ = 144
Low-pitched multiphonic (honk)
rip
sul IV
Extreme pressure (grinding)


Ee
378
fl.
ob.
fff
Lip and finger gliss.
cl.
fff
t. sax.
b. sax.
378
tr.
ff
trb.
fff
Ee
378
key.
f
Nickel Vibraphone (two-tone mallets)
perc. 1
f
half-pedal
gradually release pedal
Marimba (two-tone mallets)
lv
perc. 2
f
Ee
378
vl. 1
senza vibrato
sub p
vl. 2
senza vibrato
p
vla.
vlc.


384
fl.
Piccolo
senza vibrato
n
cresc
ob.
cl.
t. sax.
b. sax.
384
tr.
trb.
384
key.
perc. 1
Accelerate like a bouncing ball coming to rest.
mf
mp
full-pedal
perc. 2
Accelerate like a bouncing ball coming to rest.
mf
mp
384
vl. 1
vl. 2
vla.
vlc.

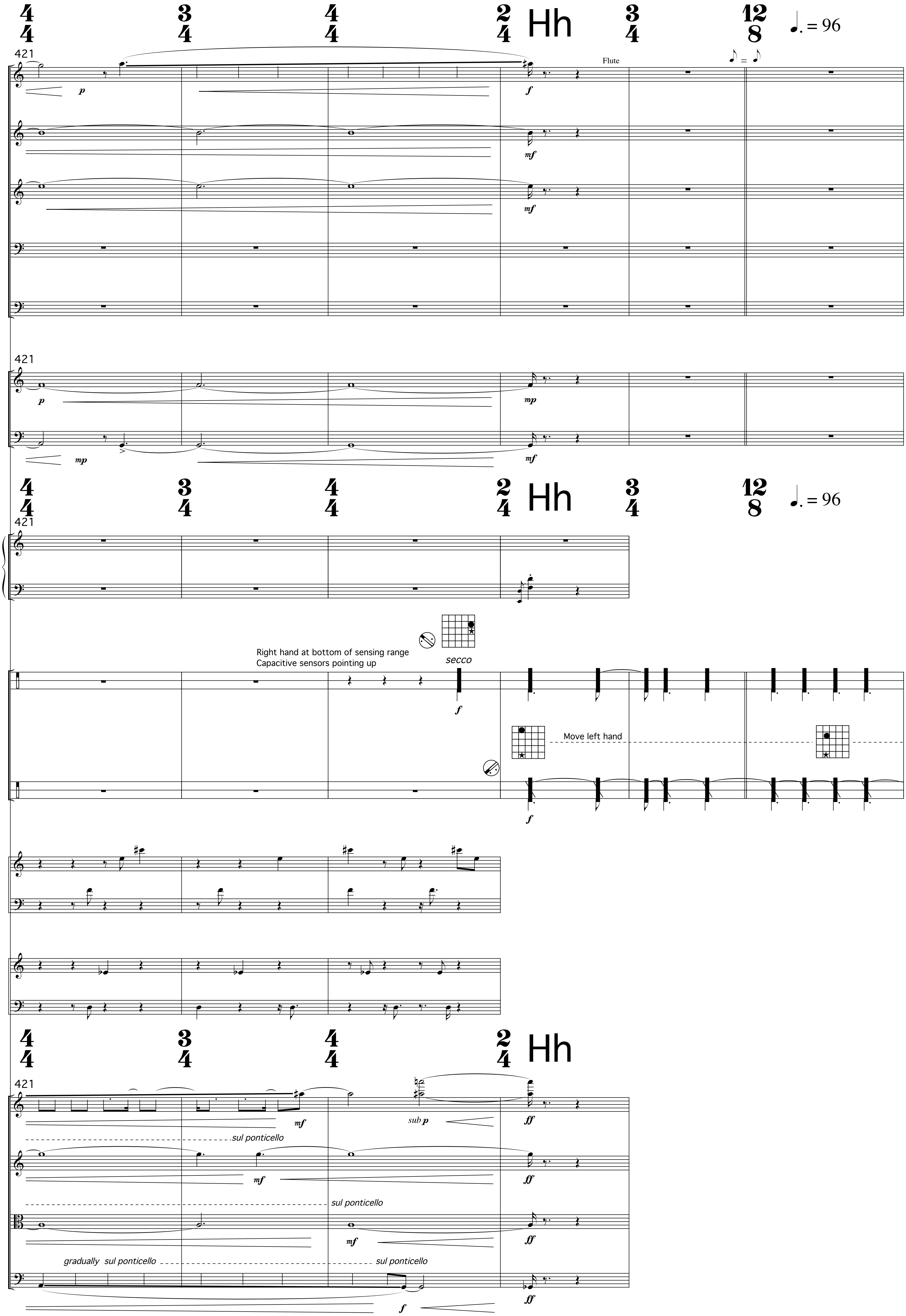

Ff
391
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
senza vibrato
pp
n
p
key.
Lp
perc. 1
perc. 2
sfz
mf
gradually release pedal
half-pedal
full-pedal
vl. 1
vl. 2
vla.
vlc.

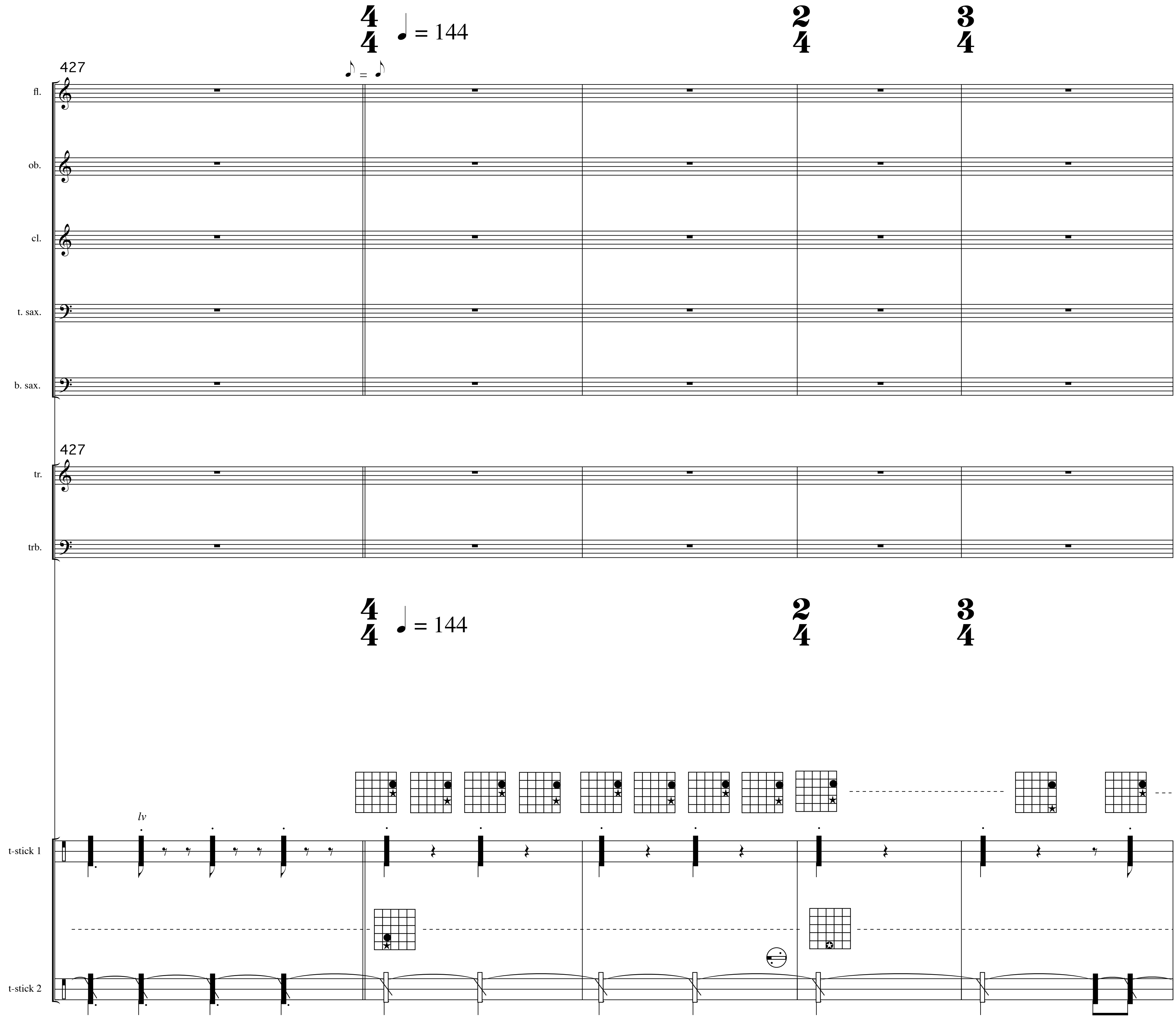

397
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
senza vibrato
tempered tuning
senza vibrato
senza vibrato


403
fl.
ob.
scordatura
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
full-pedal
perc. 2
vl. 1
vl. 2
vla.
vlc.


Gg ♩. = 96
♩ = 144
409
1/4 tone sharp
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.

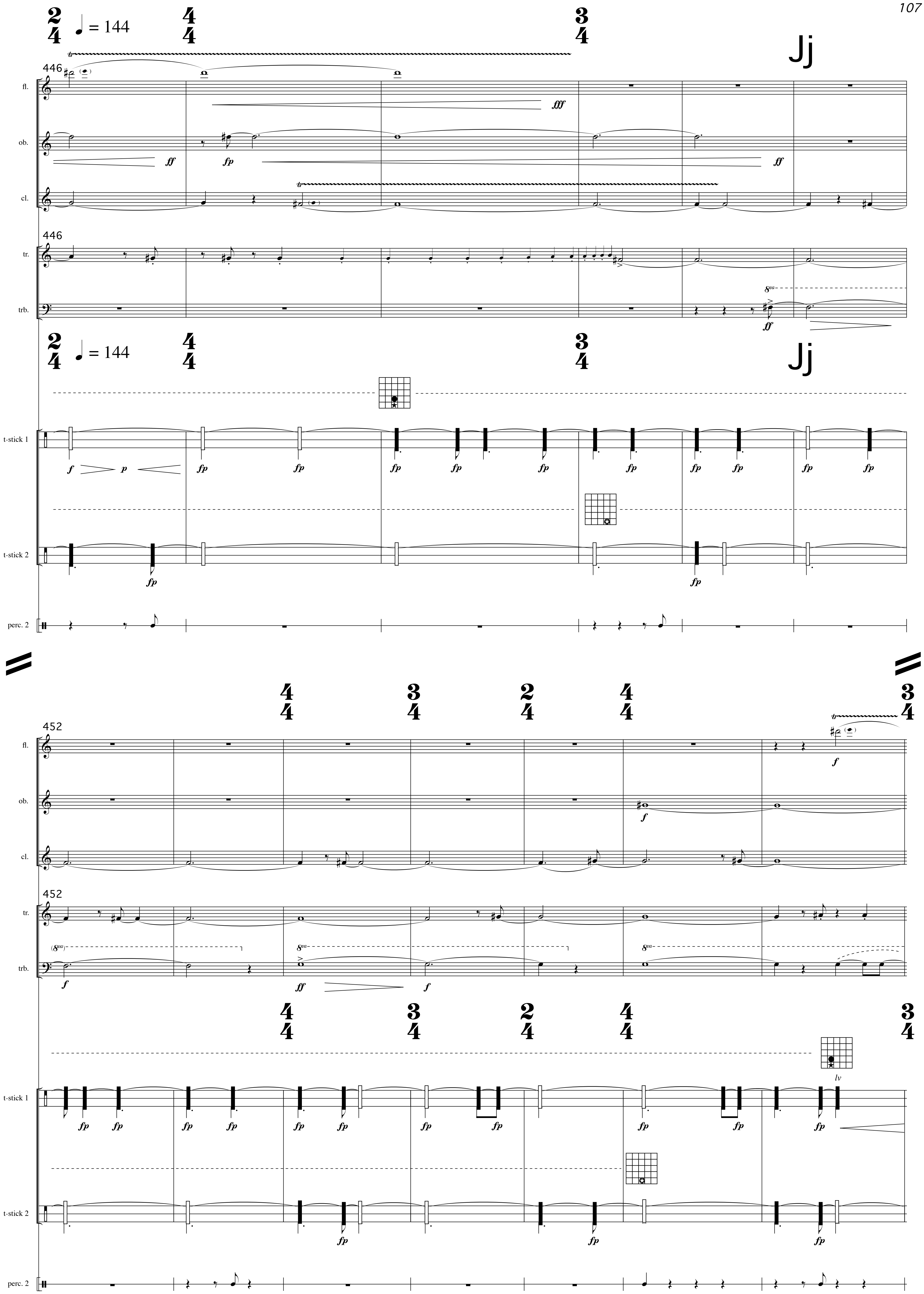

415
fl.
ppp
ob.
mf
pp
cl.
ppp
p
t. sax.
b. sax.
415
tr.
pp
trb.
pp
415
key.
mf
perc. 1
p
mf
perc. 2
p
mf
415
vl. 1
cresc
gradually sul ponticello
vl. 2
pp
gradually sul ponticello
vla.
p
pp
vlc.
p
pp

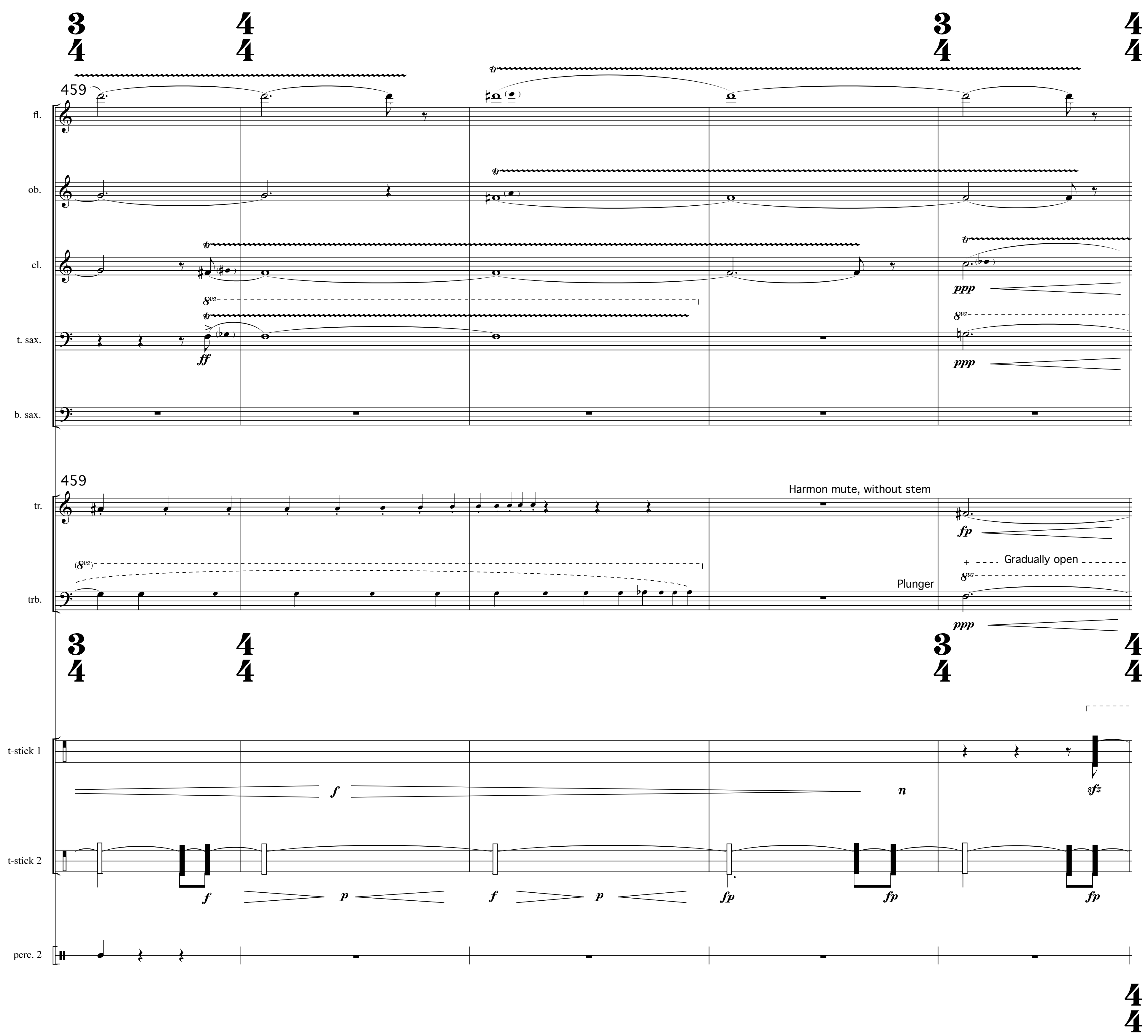

Hh
♩. = 96
421
fl.
Flute
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
Right hand at bottom of sensing range
Capacitive sensors pointing up
secco
t-stick 1
Move left hand
t-stick 2
perc. 1
perc. 2
vl. 1
sub p
sul ponticello
vl. 2
vla.
gradually sul ponticello
vlc.



427
fl.
ob.
cl.
t. sax.
b. sax.
427
tr.
trb.
= 144
= 144
lv
t-stick 1
t-stick 2


432
fl.
ob.
cl.
molto vibrato
tr.
trb.
Cup mute (tight fit)
♩. = 96
♩ = 144
Move right hand
t-stick 1
t-stick 2
Gradually move to next position
Wide frequency range
439
Flute
molto vibrato
Gradually move to next position
Slap Board
perc. 2

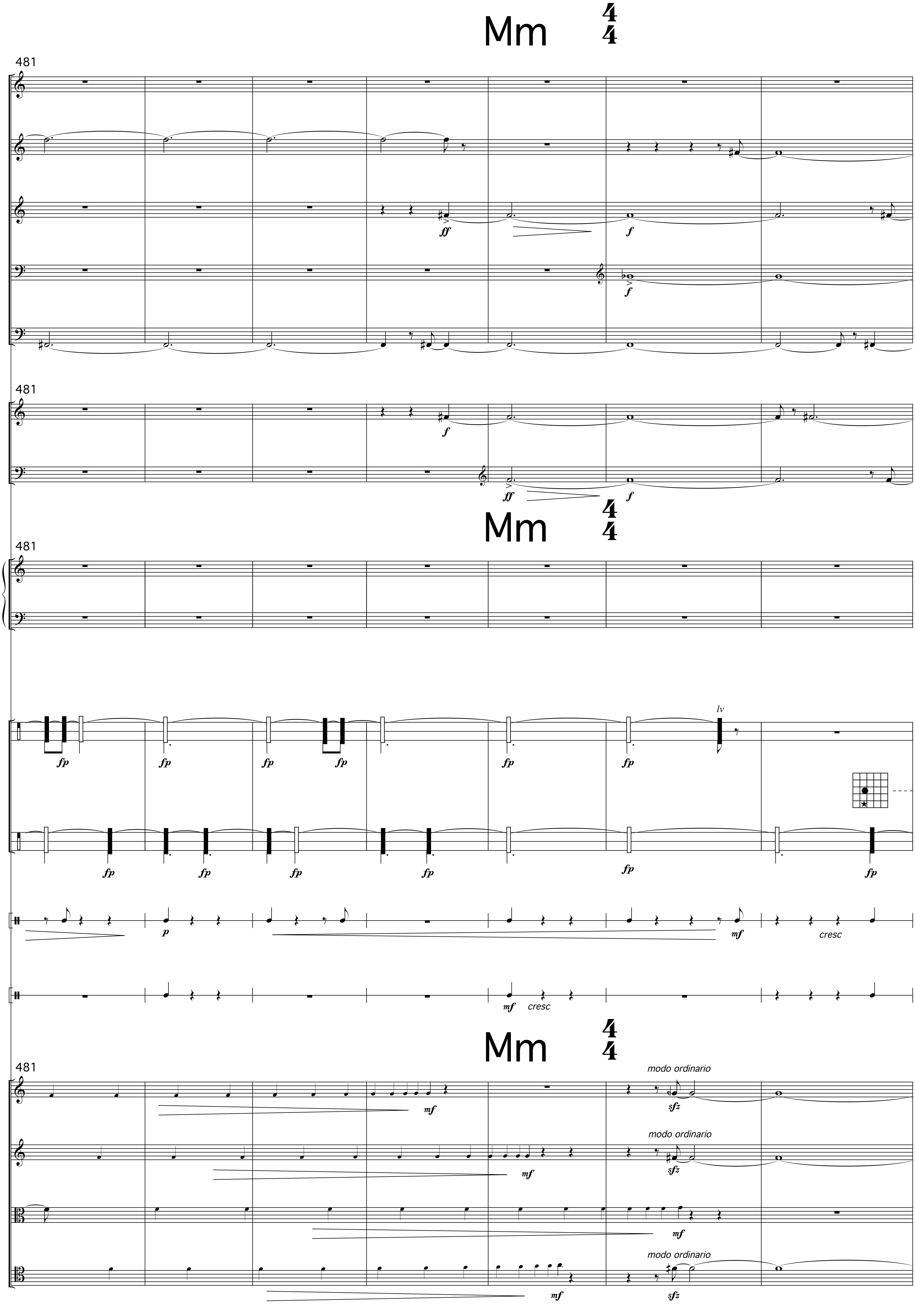

♩ = 144
Jj
446
fl.
ob.
cl.
tr.
trb.
t-stick 1
t-stick 2
perc. 2
452
lv


459
fl.
ob.
cl.
t. sax.
b. sax.
ff
ppp
459
tr.
trb.
Harmon mute, without stem
Plunger
Gradually open
fp
ppp
t-stick 1
t-stick 2
perc. 2
f
n
sfz
p
fp


Kk
464
fl.
ob.
cl.
t. sax.
b. sax.
molto vibrato
tr.
molto vibrato
trb.
No mute
Gradually move to next position
t-stick 1
t-stick 2
perc. 2
sul ponticello
marcato
Accelerate like a bouncing ball coming to rest. (on-string)
vl. 1
vl. 2
vla.
vlc.


469
fl.
ob.
cl.
t. sax.
b. sax.
molto vibrato
sub pp
cresc
tr.
trb.
No mute
t-stick 1
t-stick 2
lv
Both hands within the bottom half of the sensing range
Bass Drum (heavy beater)
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.


LI
475
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
t-stick 1
t-stick 2
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
fp simile
sul ponticello
marcato
Accelerate like a bouncing ball coming to rest.


Mm
4/4
481
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
t-stick 1
t-stick 2
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
ff
f
fp
lv
p
mf
cresc
modo ordinario
sfz


488
fl.
molto vibrato
ff
ob.
molto vibrato
cl.
t. sax.
b. sax.
488
tr.
trb.
IV
488
b3 / a6
key.
n
Gradually move to next position
Both hands near centre
Gradually shift both hands toward the bottom, keeping them close together
lv
t-stick 1
f
Move left hand
t-stick 2
f
fp
fp
perc. 1
f
perc. 2
f
488
vl. 1
vl. 2
vla.
modo ordinario
f
vlc.


Nn
493
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
Rp
Lp
lv
t-stick 1
t-stick 2
(thick wooden beater)
secco
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
cresc

497
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
Accelerate like a bouncing ball coming to rest.
key.
Wide frequency range
t-stick 1
t-stick 2
secco
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.


501
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
t-stick 1
t-stick 2
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
Straight mute
molto vibrato
Accelerate like a bouncing ball coming to rest.
b3 / a6
Rp
Lp
lv
secco
Roto Toms (hard felt)
fff
ff
fp
mp


Oo
505
fl.
ob.
cl.
t. sax.
molto vibrato
b. sax.
tr.
trb.
key.
Lp
Fan: alternate between the two positions through a fanning motion.
simile
Fluctuate dynamics in parallel with changes in position.
t-stick 1
Lasso: alternate between the two positions by continually swinging the jo overhead, 360° and counter-clockwise.
Fluctuate dynamics in parallel with changes in position.
t-stick 2
perc. 1
sul ponticello marcato
Accelerate like a bouncing ball coming to rest.
vl. 1
vl. 2
vla.
vlc.


Pp
509
fl.
ff
mf
ob.
cl.
t. sax.
f
b. sax.
tr.
trb.
key.
t-stick 1
t-stick 2
perc. 1
vl. 1
vl. 2
vla.
vlc.


513
fl.
ob.
cl.
t. sax.
b. sax.
mf
ff
f
513
tr.
trb.
513
key.
Airplane: alternate between the two positions by continually swinging the jo 360°, clockwise.
t-stick 1
Fan: alternate between the two positions through a fanning motion.
t-stick 2
perc. 1
513
vl. 1
vl. 2
vla.
vlc.
sul ponticello
marcato
ff
sul ponticello
marcato
ff


517
fl.
Piccolo
ob.
cl.
t. sax.
b. sax.
tr.
No mute
trb.
key.
simile
fan
t-stick 1
lasso
t-stick 2
perc. 1
vl. 1
modo ordinario
vl. 2
vla.
Accelerate like a bouncing
ball coming to rest.
vlc.


Qq
521
Piccolo
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
airplane
simile
t-stick 1
fan
simile
t-stick 2
perc. 1
Large Ratchet
perc. 2
vl. 1
vl. 2
vla.
vlc.


525
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
Lasso: alternate between the two positions by continually swinging the jo overhead, 360° and clockwise.
fan
simile
airplane
simile
t-stick 1
lasso
simile
fan
simile
t-stick 2
perc. 1
cresc
perc. 2
vl. 1
vl. 2
modo ordinario
vla.
modo ordinario
vlc.


Rr
529
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
Rp
Lp
fan
airplane
fan
t-stick 1
Airplane: alternate between the two positions
by continually swinging the jo 360°, counter-clockwise.
simile
fan
lasso
fan
t-stick 2
perc. 1
Achieve maximum dynamic by playing ratchet
overhead, above the height of the orchestra.
Affix to a wooden or metal resonator, if possible.
perc. 2
vl. 1
vl. 2
vla.
vlc.


533
fl.
ob.
cl.
lip gliss.
t. sax.
b. sax.
tr.
trb.
key.
f2 / f5
Wide frequency range
Very slow clockwise 'lasso' to mm 540
t-stick 1
cresc
Very slow clockwise 'lasso' to mm 540
Wide frequency range
t-stick 2
cresc
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.


537
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trbn.
key.
t-stick 1
t-stick 2
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
♩. = 96
lip gliss.
Flute
Rp
Lp
lv
sul III
sul IV


Ss
= 144
= 96
541
fl.
ob.
cl.
t. sax.
b. sax.
541
tr.
trb.
Ss
= 144
= 96
Right hand near centre
t-stick 1
t-stick 2
Ss
= 144
= 96
541
Accelerate like a bouncing
ball coming to rest. (off-string)
vl. 1
Accelerate like a bouncing
ball coming to rest. (off-string)
vl. 2
Accelerate like a bouncing
ball coming to rest.(off-string)
vla.
Accelerate like a bouncing
ball coming to rest.(off-string)
vlc.

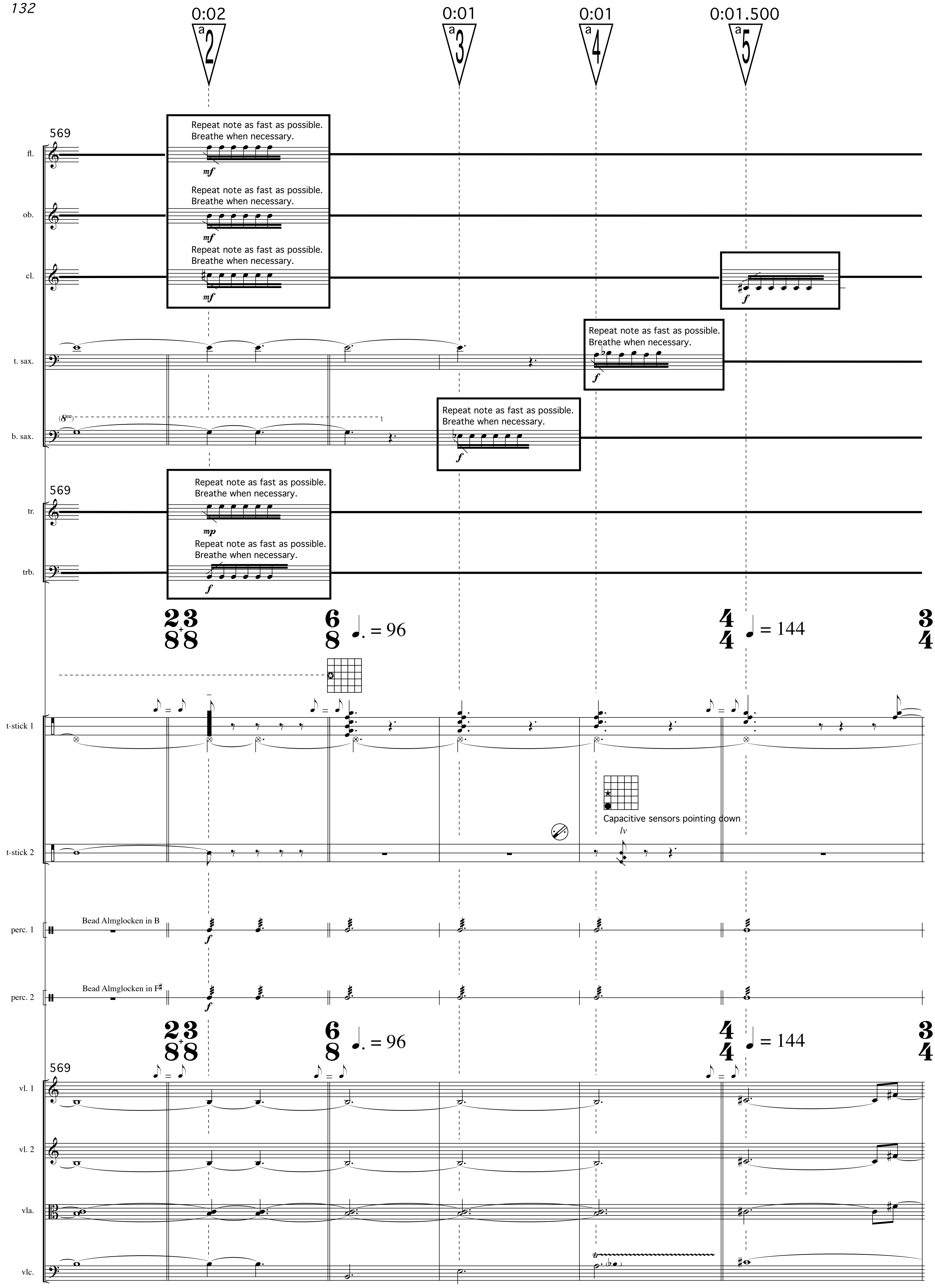

= 144
= 96
545
Flute
Tt
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
Right hand at top of sensing range
Move right hand
Move left hand
t-stick 1
t-stick 2
vl. 1
vl. 2
vla.
vlc.


549
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
t-stick 1
t-stick 2
vl. 1
vl. 2
vla.
vlc.
♩ = 144
♩. = 96
mf
f
ff

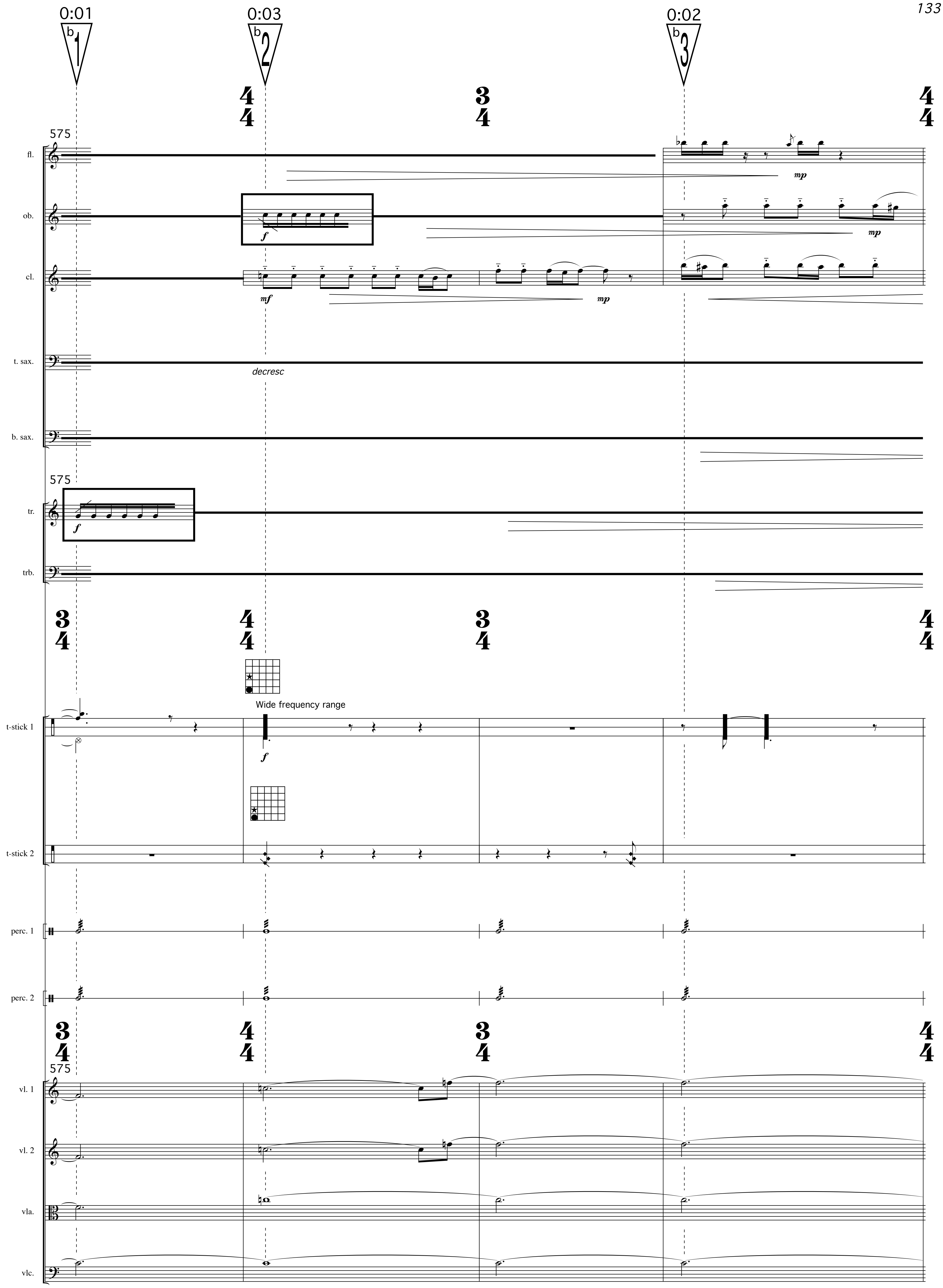

553
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
growl
Move right hand
t-stick 1
t-stick 2
vl. 1
vl. 2
vla.
vlc.


Uu
557
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
sub f
sfz
t-stick 1
t-stick 2
vl. 1
vl. 2
vla.
vlc.

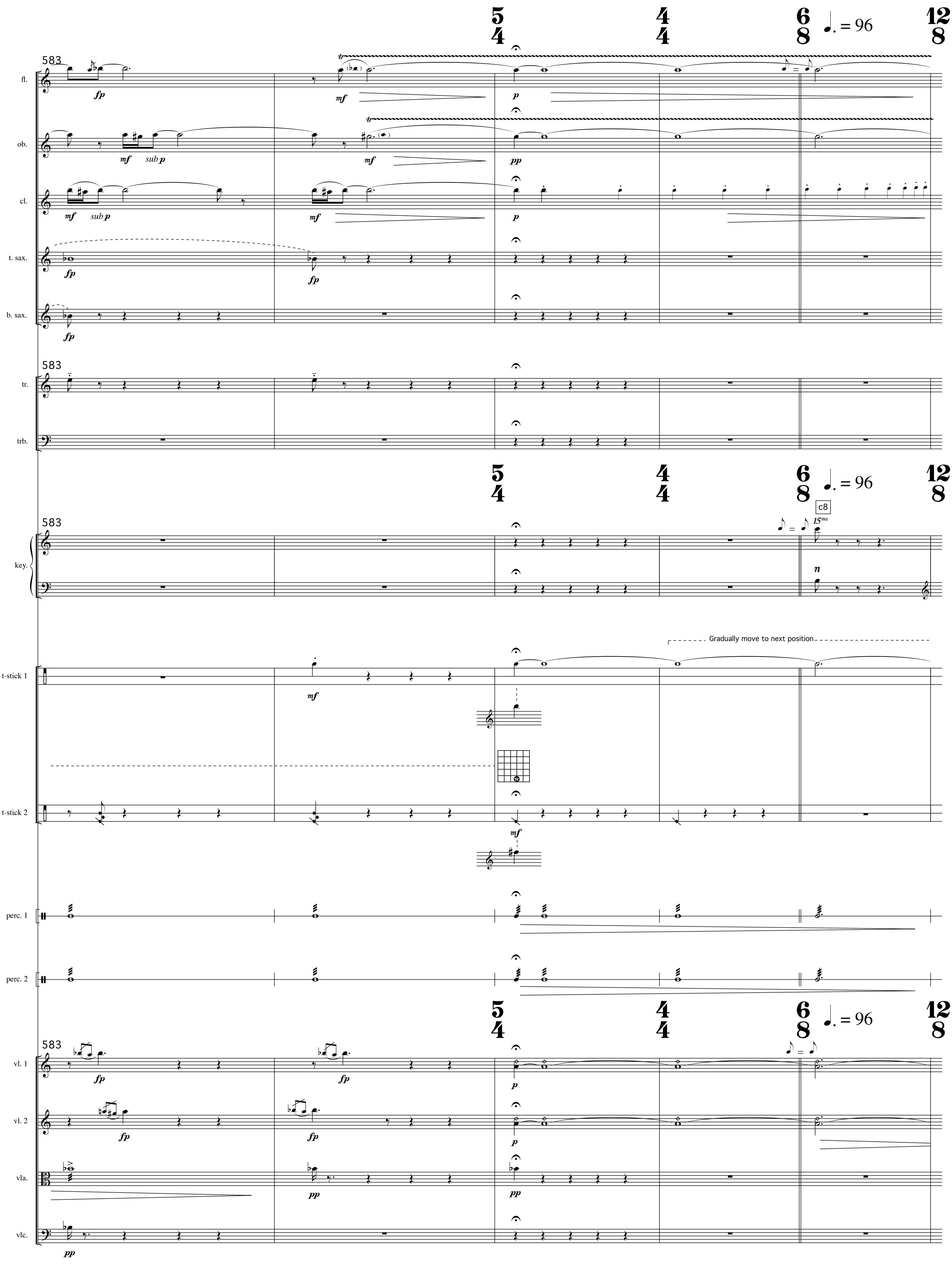
0:10
a
A time indication above a cue indicates the duration of the cue (i.e., approximate delta time between cues).
561
fl.
ob.
cl.
t. sax.
b. sax.
Free-bounce: accelerando to cue 'a2'
mf
pure tone
breathe when necessary
fp
ff
mp
8va
tr.
trb.
Free-bounce: accelerando to cue 'a2'
pure tone
f
Wide frequency range
t-stick 1
t-stick 2
vl. 1
vl. 2
vla.
vlc.



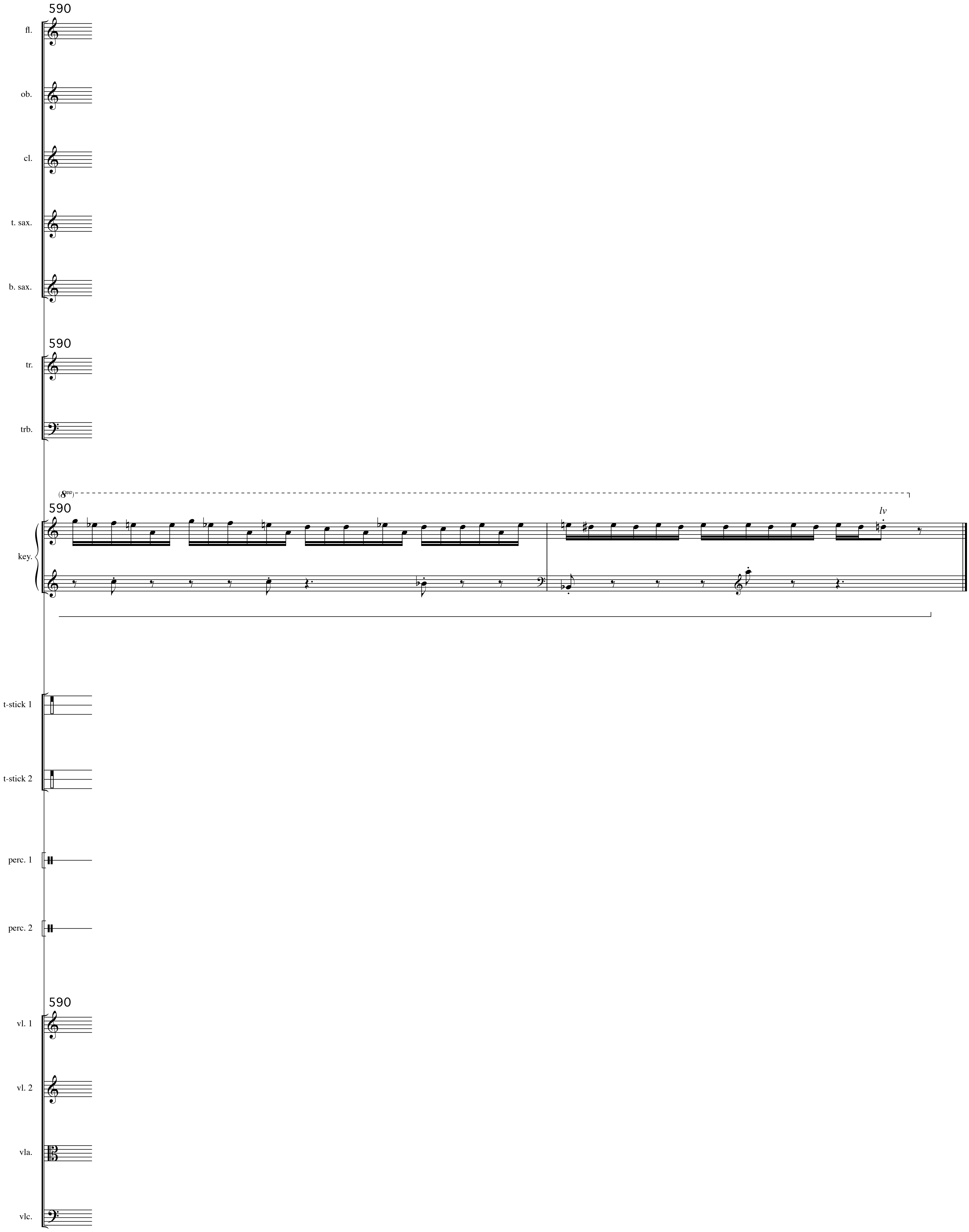
0:02
0:01
0:01
0:01.500
569
fl.
ob.
cl.
t. sax.
b. sax.
Repeat note as fast as possible.
Breathe when necessary.
mf
f
tr.
trb.
mp
= 96
= 144
t-stick 1
t-stick 2
Capacitive sensors pointing down
lv
perc. 1
Bead Almglocken in B
perc. 2
Bead Almglocken in F♯
vl. 1
vl. 2
vla.
vlc.


0:01
b 1
0:03
b 2
0:02
b 3
575
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
decresc
Wide frequency range
t-stick 1
t-stick 2
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.


0:00.500
0:01
579
fl.
ob.
cl.
t. sax.
b. sax.
pure tone
pure tone
tr.
trb.
Harmon mute, with stem
t-stick 1
t-stick 2
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
mf sub p
fp
mp


583
fl.
ob.
cl.
t. sax.
b. sax.
tr.
trb.
key.
t-stick 1
t-stick 2
perc. 1
perc. 2
vl. 1
vl. 2
vla.
vlc.
= 96
c8
15ma
Gradually move to next position
fp
mf
sub p
p
pp
n


12/8 Vv
588
fl.
pp
ob.
cl.
pp
t. sax.
b. sax.
588
tr.
trb.
12/8 Vv
588
8va
ppp
key.
Rp
lv
t-stick 1
lv
t-stick 2
perc. 1
p
perc. 2
p
12/8 Vv
588
vl. 1
pppp
vl. 2
pppp
vla.
vlc.


590
fl.
ob.
cl.
t. sax.
b. sax.
590
tr.
trb.
(8va)
590
lv
key.
t-stick 1
t-stick 2
perc. 1
perc. 2
590
vl. 1
vl. 2
vla.
vlc.